AUTOPILOT - DESCRIPTION AND OPERATION

1. Description

A. The autopilot is that portion of the auto flight control system which operates the flight control surfaces of the airplane as needed to maintain straight and level flight or to maneuver in response to pilot commands. Operating modes can be selected to provide automatic control of:

(1) Yaw damping

(2) Constant altitude

(3) Coordinated turn

(4) Vertical speed

(5) Pitch damping during turbulence

(6) Preselected compass heading

(7) Omnirange flying and localizer guidance

(8) ILS control.

B. Yaw Damper

(1) The yaw damper function can be engaged separately to provide necessary yaw damping during manual flying. Yaw damper control is not reflected at the rudder pedals.

C. Autopilot Control

(1) When the complete system is engaged, the autopilot controls the airplane in roll, pitch, and yaw axes. The existing attitude and directional reference is automatically maintained.

D. System Components (See Figure 1.)

Component	Function
(1) Autopilot Mode Annunciator	Provides visual display of radio guidance/approach mode controlling autopilot.
(2) Automatic Pilot Controller	Provides fingertip controls to enable the captain and first officer to engage the autopilot, select the

	various modes of operation, and to initiate maneuvering commands.
(3) Automatic Pilot Indicator	Provides visual indication of aileron and elevator servo drive trim conditions and output of yaw actuator position transducer. Lights indicate autopilot off, glide path armed, auto trim off.
(4) Autopilot Release Switches	Provide disengagement of the roll and pitch axes of the autopilot.
(5) Accelerometers (six required)	Translate acceleration in yaw, roll, and pitch axes into electrical signals for damping short-period attitude changes.
(6) Servo Drives and Brackets (two required)	Initiate movement of the ailerons and elevator in response to amplified signals from the roll and pitch channels.
(7) Yaw Axis Electrohydraulic Transfer Valve (part of rudder hydraulic power package)	Provides the means for yaw channel input to the main control valve in the rudder hydraulic power package.
(8) Roll Channel Computer	Provides roll axis interlock; computes and shapes error and command signals to drive the aileron servo drive.
(9) Yaw Channel Computer	Provides automatic stability augmentation and turn coordination in response to command signals from the autopilot sensing and control devices.
(10) Pitch Channel Computer	Provides pitch axis interlock; computes and shapes error and command signals to drive the elevator servo drive.
(11) Air Data Computer	Provides signals for autopilot vertical speed, altitude hold, Mach Q_c/p data, and airspeed (Q) switching of autopilot command parameters.

2. Operation

A. Yaw Axis

(1) Synchronization

(a) With yaw axis circuit breakers closed and power applied, the autopilot provides self-synchronization within the yaw channel computer. The synchronization provides a null output from the torquer amplifier to the electrohydraulic transfer valve. With pitch and roll axes circuit breakers also closed, synchronization to airplane magnetic heading, as sensed by the directional gyro, is provided within the yaw channel computer by a heading synchronizer. The heading reference output signal is routed to the roll channel computer.

(2) Yaw Damper

(a) The yaw damper mode is engaged when yaw axis ac and dc circuit breakers are closed and the servos engage lever on the automatic pilot controller is moved to yaw damper position. The servos engage lever is held at the yaw damper position if all yaw axis engage path interlock requirements are met. The yaw channel computer provides rudder command signals to dampen the airplane dutch roll characteristics during manually and automatically controlled flight. Because of the rudder hydraulic and linkage tie-ins with the manual controls, yaw damper control actions are not reflected at the rudder pedals. Further, the pilot can maneuver the airplane in a normal manner through the rudder pedals with no opposing force or action from the yaw damper.

(b) With pitch and roll axes circuit breakers closed, and the autopilot mode engaged, the yaw channel computer also provides rudder command signals to assist turn maneuvers.

(3) Autopilot

(a) The autopilot mode is engaged when yaw axis, pitch and roll axes, and air data circuit breakers are closed and the servos engage lever is set at autopilot. This continues yaw damper operation and also engages the roll and pitch axes. The yaw, roll, and pitch axes are series interlocked for autopilot control. When an interlock interruption occurs in any axis, the autopilot mode is automatically disengaged. If the pitch or roll axis is malfunctioning, the servos engage lever drops to yaw damper position and the autopilot off light comes on as an indication to the pilot. The light remains on until one of the autopilot release buttons is pressed.

(b) During the approach phase of ILS operation, the yaw channel computer receives a roll command to rudder signal that compensates for long-term airplane heading asymmetries such as loss of an engine. In

addition, a heading synchronizer in the yaw computer module receives heading signals from the directional gyro and provides heading reference and heading error data to the roll channel computer for heading hold functions.

B. Roll Axis

(1) Synchronization

(a) With pitch and roll circuit breakers closed and power applied, the autopilot provides continuous synchronization to airplane roll attitude and magnetic heading. This synchronization provides a null output from the aileron servo amplifier to the aileron servo drive motor.

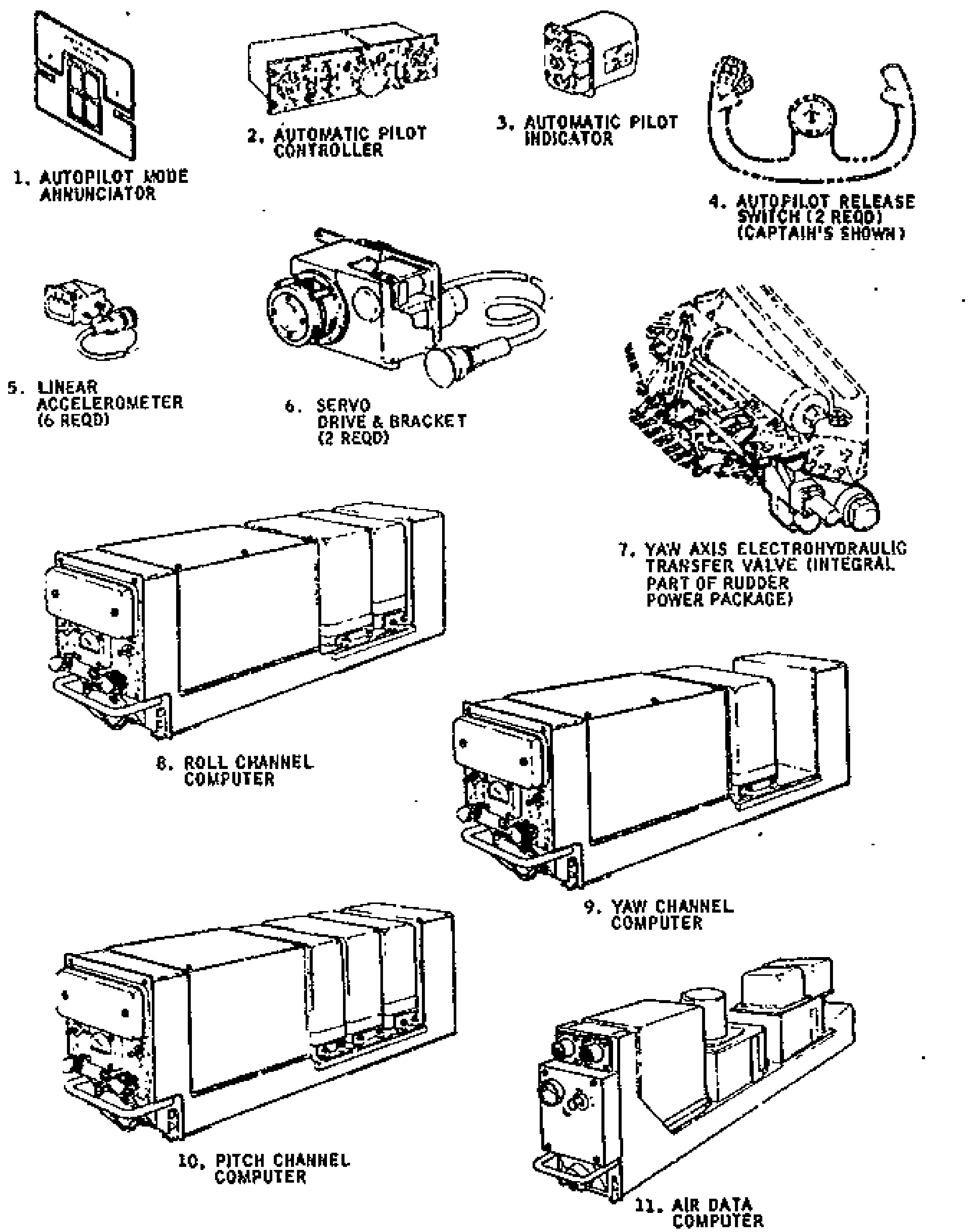
(2) Roll Axis Engage

(a) The roll axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot position if all engage path interlock requirements are met.

(b) If the roll axis is engaged when the aircraft is at a roll angle (up to 35 degrees), the airplane automatically returns smoothly to a wings-level condition. When the airplane roll angles reduces to less than 6 degrees, the autopilot automatically couples the airplane to the compass heading (compass system).

(c) Heading hold is initiated with the navigation selector switch on the automatic pilot controller at turn knob and the turn knob at detent, heading hold is automatically established when airplane bank angle is less than 6 degrees.

(d) Automatic disengagement of the autopilot mode occurs when the roll axis monitor detects a malfunction within the roll axis. The servos engage lever drops to yaw damper, and the autopilot off light comes on as an indication to the pilot.



Autopilot System Components
Figure 1

(3) Turn Knob

(a) The turn knob located on the automatic pilot controller is the primary roll control mode. The knob provides a manual turn control function for changing airplane heading. The turn knob must be in detent to engage the autopilot.

(b) The turn knob operates through the roll axis (aileron channel) to establish and hold the desired bank angle required to initiate a heading change. The degree and direction of bank angle is proportional to the amount and direction of turn knob rotation. When the turn knob is moved from detent, the roll axis automatically decouples from the heading reference. As long as the turn knob is left out of detent, the airplane remains in a turn at the commanded bank angle. When the turn knob is returned to the detent position, the airplane returns to wings level and is recoupled to the heading reference which exists when bank angle becomes less than 6 degrees. Operation of the turn knob takes priority over any lateral control mode.

(4) Heading Select

(a) The heading select mode operates through the roll axis to establish and follow a chosen heading set on the course indicator or equivalent heading display. The heading select cursor on the indicator is positioned at the desired heading by using the heading select sync knob. With the navigation selector switch set to heading select, the airplane is automatically banked at a controlled roll rate up to a limited bank angle to execute a turn toward the selected heading. As this heading is approached, the airplane is smoothly brought to wings-level. The airplane is aligned with the selected heading and is directed to maintain that heading until new commands are given to the autopilot.

(5) Localizer/Omnirange

(a) The roll channel computer provides aileron control in response to lateral radio signals (VOR and ILS) if the navigation selector switch is rotated to LOC/VOR and the navigation receiver is tuned to the proper frequency. Desired omniradial heading or inbound runway heading must be set on the pictorial deviation indicator.

(b) Automatic beam capture is initiated by the pilot establishing an appropriate intercept heading, using either the turn knob or heading select mode. After the airplane rolls out on the intercept course, rotating the navigation selector switch to LOC/VOR establishes heading hold until lateral beam intercept.

(c) At beam intercept, the airplane turns toward the transmitting station at a limited bank angle that is a function of beam error, rate of change of beam error (ILS only), and course runway heading error. When the airplane attains the selected radial at beam center

(on-course) the autopilot automatically integrates for crosswind correction. As the airplane approaches the zone-of-confusion above the VOR transmitter, interlocks decouple the beam signal, and the airplane is directed to fly at the drift-corrected radial heading. After passing the VOR station, the beam is again switched into roll command circuitry, and the autopilot tracks the outbound radial.

(6) ILS

(a) With the navigation selector switch set to ILS at a specified beam error, glide path control is initiated. The pitch channel computer controls descent to glide path beam center while the roll channel computer maintains the airplane on localizer beam center to minimum altitude or disengagement.

(b) Interlocks prevent selection of ILS unless the pitch axis is engaged and appropriate radio receiver is tuned to ILS frequency. The navigation selector switch will not hold in ILS, and glide path capture is prevented.

(7) Auxiliary Navigation Control (Optional)

The autopilot roll axis provides automatic control in response to track error and cross track deviation information received from an auxiliary navigation system to maintain a selected ground track or sequence of ground tracks. Auxiliary navigation is engaged by pressing and rotating the navigation selector switch to AUX NAV after setting the initial conditions in the auxiliary navigation controller. Upon engagement, the airplane will automatically be turned to intercept auxiliary navigation track. Auxiliary navigation control of the airplane is implemented only in airplanes equipped with auxiliary navigation systems.

C. Pitch Axis

(1) Synchronization

(a) With pitch and roll circuit breakers closed and power applied, the autopilot provides continuous synchronization of airplane pitch attitude, vertical speed, and altitude. This synchronization provides a null output from the elevator servo amplifier to the elevator servo drive motor prior to engagement.

(2) Pitch Axis Engage

(a) The pitch axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot if all engage path interlock requirements are met.

(b) When engaged, the pitch axis provides a vertical speed hold function. This is the primary pitch control mode. It adjusts the pitch attitude of the airplane to maintain the vertical speed existing when the pitch axis was engaged. The vertical speed hold function continues until changed by use of the vertical speed wheel on the automatic pilot controller.

(c) Automatic disengagement of autopilot control occurs when the pitch axis monitor detects a malfunction within the pitch axis. The servos engage lever drops to yaw damper and the autopilot off light comes on as an indication to the pilot.

(3) Vertical Speed Control

(a) The detent (center) position of the vertical speed wheel is altitude hold (zero vertical speed). During synchronization, the motor-driven vertical speed wheel follows up to the vertical speed of the airplane, providing a vertical speed reference for the vertical speed hold function at engagement.

(b) When the vertical speed wheel is moved out of detent, the airplane assumes (and adjusts as required) a pitch attitude to hold the commanded vertical speed. The pilot observes the rate of climb (or descent) on the vertical speed indicator and manually adjusts the vertical speed wheel to obtain the desired vertical speed. The pitch selector switch returns to vertical speed when the vertical speed wheel is manually moved. The navigation selector switch returns to turn knob when the airplane is under glide path control mode if the vertical speed knob is manually moved. If the system is in the glide path extension mode (and was manually or automatically engaged to this mode), manual movement of the vertical speed wheel reverts the system to the turn knob and vertical speed modes.

(4) Altitude Hold

(a) Altitude hold is established when the vertical speed wheel is at altitude hold (zero vertical speed). The airplane altitude existing when the vertical speed wheel is returned to the detent (altitude hold) position is maintained until a change in vertical speed is commanded.

(5) Pitch Damp

(a) When the pitch selector switch is pressed and rotated to the pitch damp position, the pitch damp mode is initiated. During this mode, which is used for turbulence penetration, automatic pitch trim is disconnected. Pitch trim is accomplished by manual actuation of the horizontal stabilizer controls. A "soft" pitch attitude damping function is provided by the autopilot to minimize pitch rate deviations. There is no vertical gyro pitch attitude reference during operation of pitch damp mode.

(6) Glide Path Control - Automatic

(a) The autopilot pitch axis provides automatic glide path control from signals received from a glide path receiver. The system automatically captures the glide path beam when the pitch axis is engaged, the glide path receiver is tuned to an ILS frequency, and the navigation selector switch is at ILS. At glide path capture the pitch selector switch returns to vertical speed if the switch was at another position.

(b) A 10-second capture period begins at glide path capture. During this period, a fixed vertical speed command is applied to the pitch channel computer, causing the airplane to descend at approximately 700 feet per minute. The vertical speed wheel follows up to this commanded rate of descent.

(c) After the 10-second capture period terminates, the airplane is in the glide path control phase. In this phase, the airplane follows the glide path beam.

(d) The vertical speed wheel follows up to the rate of descent during the control phase. Heading, localizer, and glide path gain programing are initiated as a function of radio altimeter altitude (analog dc output). If the radio altimeter malfunctions, localizer and glide path gains are programed at glide path capture to compensate for ILS beam convergence. The control phase ends when the pilot terminates the automatic approach to land the airplane manually.

(7) Glide Path Extension

The glide path extension mode is manually engaged by placing the pitch selector switch at G/P EXT. This mode can be used by the pilot to initiate glide path second stage gain programing only when glide path is energized (capture +10 seconds), the radio altimeter has failed or is not connected to the autopilot, and the middle marker beacon is not passed. If the radio altimeter is disabled or not installed, glide path gains are second-stage programed automatically upon interception of the middle marker beacon.

AUTOPILOT - DESCRIPTION AND OPERATION

1. Description

A. The autopilot is that portion of the auto flight control system which operates the flight control surfaces of the airplane as needed to maintain straight and level flight or to maneuver in response to pilot commands. Operating modes can be selected to provide automatic control of:

(1) Yaw damping

(2) Constant altitude

(3) Coordinated turn

(4) Vertical speed

(5) Constant indicated airspeed

(6) Pitch damping during turbulence

(7) Preselected compass heading

(8) Omnirange flying and localizer guidance

(9) ILS control.

B. Yaw Damper

(1) The yaw damper function can be engaged separately to provide necessary yaw damping during manual flying. Yaw damper control is not reflected at the rudder pedals.

C. Autopilot Control

(1) When the complete system is engaged, the autopilot controls the airplane in roll, pitch, and yaw axes. The existing attitude and directional reference is automatically maintained.

D. System Components (see Figure 1.)

Component	Function
(1) Autopilot Mode Annunciator	Provides visual display of radio guidance/approach mode controlling autopilot.
(2) Automatic Pilot Controller	Provides fingertip controls to enable the captain and first officer to engage the autopilot, select the various modes of operation, and to initiate maneuvering commands.
(3) Automatic Pilot Indicator	Provides visual indication of aileron and elevator servo drive trim conditions and output of yaw actuator position transducer. Lights indicate autopilot off, glide path armed, auto trim off.
(4) Autopilot Release Switches	Provide disengagement of the roll and pitch axes of the autopilot.
(5) Accelerometers (six required)	Translate acceleration in yaw, roll, and pitch axes into electrical signals for damping short-period attitude changes.
(6) Servo Drives and Brackets (two required)	Initiate movement of the ailerons and elevator in response to amplified signals from the roll and pitch channels.
(7) Yaw Axis Electrohydraulic Transfer Valve (part of rudder hydraulic power package)	Provides the means for yaw channel input to the main control valve in the rudder hydraulic power package.
(8) Roll Channel Computer	Provides roll axis interlock; computes and shapes error and command signals to drive the aileron servo drive.
(9) Yaw Channel Computer	Provides automatic stability augmentation and turn coordination in response to command signals from the autopilot sensing and control devices.

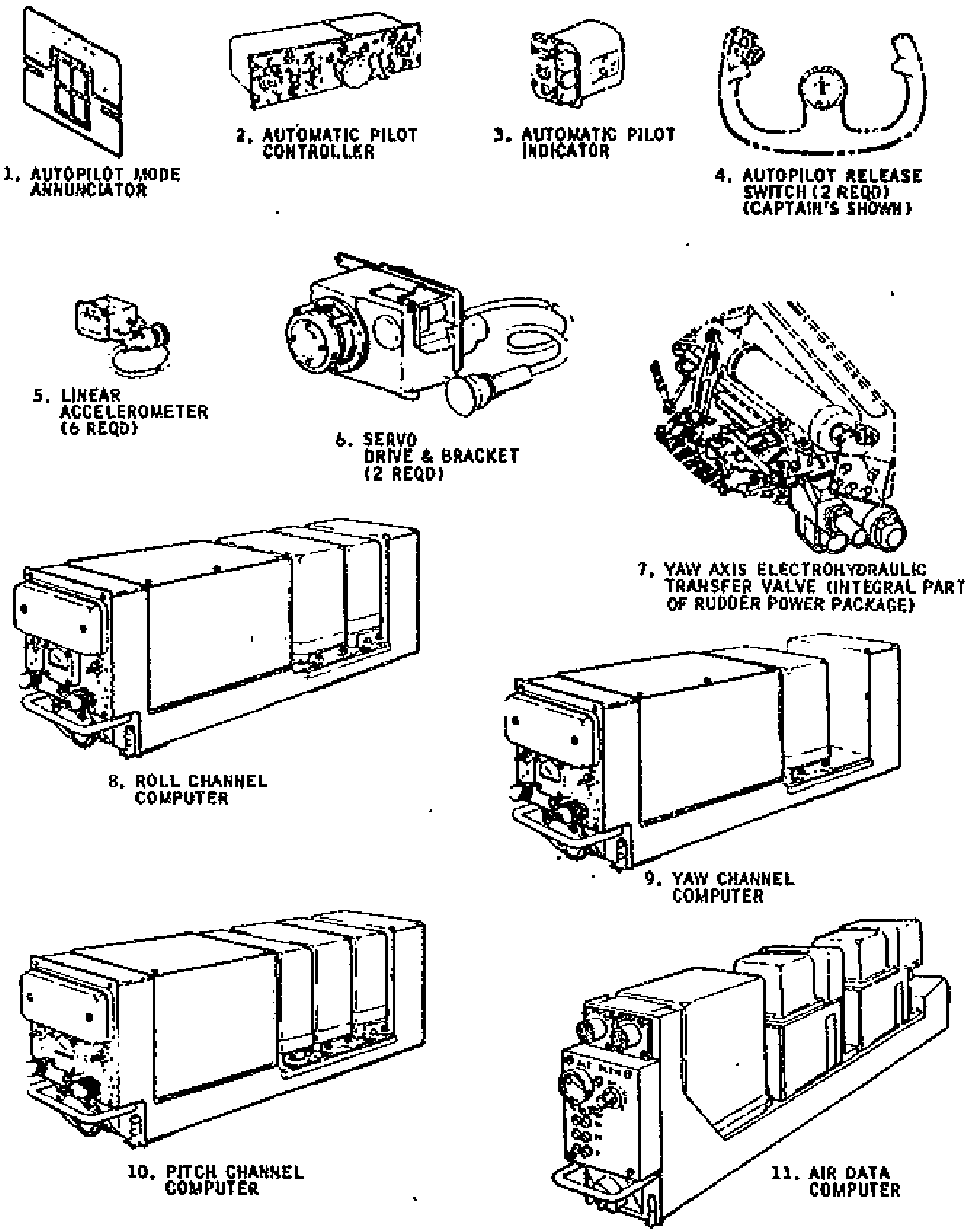
Component	Function
(10) Pitch Channel Computer	Provides pitch axis interlock; computes and shapes error and command signals to drive the elevator servo drive.
(11) Air Data Computer	Provides signals for autopilot vertical speed, altitude hold, Mach Q_c/p data airspeed (Q) switching of autopilot command parameters, and airspeed data.

2. Operation

A. Yaw Axis

(1) Synchronization

(a) With yaw axis circuit breakers closed and power applied, the autopilot provides self-synchronization within the yaw channel computer. The synchronization provides a null output from the torquer amplifier to the rudder electrohydraulic transfer valve. With pitch and roll axes circuit breakers also closed, synchronization to airplane magnetic heading, as sensed by the directional gyro, is provided within the yaw channel computer by a heading synchronizer. The heading reference output signal is routed to the roll channel computer.



HA2-2536A

Autopilot System Components
Figure 1

(2) Yaw Damper

(a) The yaw damper mode is engaged when yaw axis ac and dc circuit breakers are closed and the servos engage lever on the automatic pilot controller is moved to yaw damper position. The servos engage lever is held at the yaw damper position if all yaw axis engage path interlock requirements are met. The yaw channel computer provides rudder command signals to dampen the airplane dutch roll characteristics during manually and automatically controlled flight. Because of the rudder hydraulic and linkage tie-ins with the manual controls, yaw damper control actions are not reflected at the rudder pedals. Further, the pilot can maneuver the airplane in a normal manner through the rudder pedals with no opposing force or action from the yaw damper.

(b) With the autopilot 115-volt ac circuit breaker closed and the autopilot mode engaged. The yaw channel computer also provides rudder command signals to assist turn maneuvers.

(3) Autopilot

(a) The autopilot mode is engaged when yaw axis, pitch and roll axes, and air data circuit breakers are closed and the servos engage lever is set to autopilot. This continues yaw damper operation and also engages the roll and pitch axes. The yaw, roll, and pitch axes are series interlocked for autopilot control. When an interlock interruption occurs in any axis, the autopilot mode is automatically disengaged. If the pitch or roll axis is malfunctioning, the servos engage lever drops to yaw damper position, and the autopilot off light comes on as an indication to the pilot. The light remains on until one of the autopilot release buttons is pressed.

(b) During the approach phase of ILS operation, the yaw channel computer receives a roll command to rudder signal that compensates for long-term airplane heading asymmetries such as loss of an engine. In addition, a heading synchronizer in the yaw computer module receives heading signals from the directional gyro and provides heading reference and heading error data to the roll channel computer for heading hold functions.

B. Roll Axis

(1) Synchronization

(a) With pitch and roll circuit breakers closed and power applied, the autopilot provides continuous synchronization to airplane roll attitude and magnetic heading. This synchronization provides a null output from the aileron servo amplifier to the aileron servo drive motor.

(2) Roll Axis Engage

(a) The roll axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot position if all engage path interlock requirements are met.

(b) If the roll axis is engaged when the aircraft is at a roll angle up to 35 degrees the airplane automatically returns smoothly to a wings level condition. When the airplane roll angle reduces to less than 6 degrees, the autopilot automatically couples the airplane to the compass heading (compass system).

(c) Heading hold is with the navigation selector switch on the automatic pilot controller at turn knob and the turn knob at detent, heading hold is automatically established when airplane bank angle is less than 6 degrees.

(d) Automatic disengagement of the autopilot mode occurs when the roll axis monitor detects a malfunction within the roll axis. The servos engage lever drops to yaw damper, and the autopilot off light comes on as an indication to the pilot.

(3) Turn Knob

(a) The turn knob located on the automatic pilot controller is the primary roll control mode. The knob provides a manual turn control function for changing airplane heading. The turn knob must be in detent to engage the autopilot.

(b) The turn knob operates through the roll axis (aileron channel) to establish and hold the desired bank angle required to initiate a heading change. The degree and direction of bank angle is proportional to the angle and direction of turn knob rotation. When the turn knob is moved from detent, the roll axis automatically decouples from the heading reference. As long as the turn knob is left out of detent, the airplane remains in a turn at the commanded bank angle. When the turn knob is returned to the detent position, the airplane returns to wings level and is recoupled to the heading reference which exists when bank angle becomes less than 6 degrees. Operation of the turn knob takes priority over any lateral control mode.

(4) Heading Select

(a) The heading select mode operates through the roll axis to establish and follow a chosen heading set on the course indicator or equivalent heading display. The heading select cursor on the indicator is positioned at the desired heading by using the heading select sync knob. With the navigation selector switch set to heading select, the airplane is automatically banked at a controlled roll rate up to a limited bank angle to execute a turn toward the selected heading. As this heading is approached, the airplane is smoothly brought to wings-level. The airplane is aligned with the selected heading and is directed to maintain that heading until new commands are given to the autopilot.

(5) Localizer/Omnirange

(a) The roll channel computer provides aileron control in response to lateral radio signals (VOR and ILS) if the navigation switch is rotated to LOR/VOR and the navigation receiver is tuned to the proper frequency. Desired omniradial heading or inbound runway heading must be set on the pictorial deviation indicator.

(b) Automatic beam capture is initiated by the pilot establishing an appropriate intercept heading, using either the turn knob or heading select mode. After the airplane rolls out on the intercept course, rotating the navigation selector switch to LOC/VOR establishes heading hold until lateral beam intercept.

(c) At beam intercept, the airplane turns toward the transmitting station at a limited bank angle that is a function of beam error, rate of change of beam error (ILS only), and course (runway) heading error. When the airplane attains the selected radial at beam center (on-course) the autopilot automatically integrates for crosswind correction. As the airplane approaches the zone-of-confusion above the VOR transmitter, interlocks decouple the beam signal, and the airplane is directed to fly at the drift-corrected radial heading. After passing the VOR station, the beam is again switched into roll command circuitry, and the autopilot tracks the outbound radial.

(6) ILS

(a) With the navigation selector switch set to ILS at a specified beam error, glide path control is initiated. The pitch channel computer controls descent to glide path beam center while the roll channel computer maintains the airplane on localizer beam center to minimum altitude on disengagement.

(b) Interlocks prevent selection of ILS unless the pitch axis is engaged and appropriate radio receiver is tuned to ILS frequency. The navigation selector switch will not hold in ILS and glide path capture is prevented.

(7) Auxiliary Navigation Control (optional)

(a) The autopilot roll axis can provide automatic control in response to track error and cross track deviation information received from auxiliary navigation system to maintain a selected ground track or sequence of ground tracks: Auxiliary navigation is engaged by pressing and rotating the navigation selector switch to AUX NAV after setting the initial conditions in the auxiliary navigation controller. Upon engagement, the airplane is automatically turned to intercept auxiliary navigation track. Auxiliary navigation control of the airplane is implemented only in airplanes equipped with doppler systems.

C. Pitch Axis

(1) Synchronization

(a) With pitch and roll circuit breakers closed and power applied, the autopilot provides continuous synchronization of airplane pitch attitude, vertical speed, and altitude. This synchronization provides a null output from the elevator servo amplifier to the elevator servo drive motor prior to engagement.

(2) Pitch Axis Engage

(a) The pitch axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot if all engage path interlock requirements are met.

(b) When engaged, the pitch axis provides a vertical speed hold function. This is the primary pitch control mode. It adjusts the pitch attitude of the airplane to maintain the vertical speed existing when the pitch axis was engaged. The vertical speed hold function continues until changed by use of the vertical speed wheel on the automatic pilot controller.

(c) Automatic disengagement of autopilot control occurs when the pitch axis monitor detects a malfunction within the pitch axis. The servos engage lever drops to yaw damper and the autopilot off light comes on as an indication to the pilot.

(3) Vertical Speed Control

(a) The detent (center) position of the vertical speed wheel is altitude hold (zero vertical speed). During synchronization, the motor-driven vertical speed wheel follows up to the vertical speed of the airplane, providing a vertical speed reference for the vertical speed hold function at engagement.

(b) When the vertical speed wheel is moved out of detent, the airplane assumes and adjusts as required a pitch attitude to hold the commanded vertical speed. The pilot observes the rate of climb or descent on the vertical speed indicator and manually adjusts the vertical speed wheel to obtain the desired vertical speed. The pitch selector switch returns to vertical speed when the vertical speed wheel is manually moved. The navigation selector switch returns to turn knob when the airplane is under glide path control mode if the vertical speed knob is manually moved. If the system is in the glide path extension mode and was manually or automatically engaged to this mode, manual movement of the vertical speed wheel reverts the system to the turn knob and/or vertical speed modes.

(4) Altitude Hold

(a) Altitude hold is established when the vertical speed wheel is at altitude hold (zero vertical speed). The airplane altitude existing when the vertical speed wheel is returned to the detent (altitude hold) position is maintained until a change in vertical speed is commanded.

(5) Pitch Damp

(a) When the pitch selector switch is pressed and rotated to the pitch damp position, the pitch damp mode is initiated. During this mode, which is used for turbulence penetration, automatic pitch trim is disconnected. Pitch trim is accomplished by manual actuation of the horizontal stabilizer controls. A "soft" pitch attitude damping function is provided by the autopilot to minimize pitch rate deviations. There is no vertical gyro pitch attitude reference during operation of pitch damp mode.

(6) Glide Path Control - Automatic

(a) The autopilot pitch axis provides automatic glide path control from signals received from a glide path receiver. The system automatically captures the glide path beam when the pitch axis is engaged, the glide path receiver is tuned to an ILS frequency, and the navigation selector switch is at ILS. At glide patch capture, the pitch selector switch returns to vertical speed if the switch was at another position.

(b) A 10-second capture period begins at glide path capture. During this period, a fixed vertical speed command is applied to the pitch channel computer, causing the airplane to descend at approximately 700 feet per minute. The vertical speed wheel follows up to this commanded rate of descent.

(c) After the 10-second capture period terminates, the airplane is in the glide path control phase. In this phase, the airplane follows the glide path beam.

(d) The vertical speed wheel follows up to the rate of descent during the control phase. Heading, localizer, and glide path gain programming are initiated as a function of radio altimeter altitude (analog dc output). If the radio altimeter malfunctions, localizer and glide path gains are programmed at glide path capture to compensate for ILS beam convergence. The control phase ends when the pilot terminates the automatic approach to land the airplane manually.

(7) Glide Path Extension

(a) The glide path extension mode is manually engaged by placing the pitch selector switch at G/P EXT. This mode can be used by the pilot to initiate glide path second-stage gain programming only when glide path is energized (capture +10 seconds), the radio altimeter has failed or is not connected to the autopilot, and the middle marker is not passed. If the radio altimeter is disabled or not installed, glide path gains are second-stage programmed automatically upon interception of the middle marker beacon.

(8) IAS Hold

(a) The IAS (indicated airspeed) hold mode is engaged by moving the pitch selector switch to the IAS hold position. The indicated airspeed existing at the time of engagement is maintained by automatic adjustment of the airplane pitch attitude.

(b) With the pitch axis engaged, the vertical speed hold function automatically controls vertical speed. When the desired indicated airspeed is attained, the pitch selector switch is rotated to the IAS hold position. Automatic elevator control adjusts pitch attitude to maintain the desired airspeed; throttle adjustment will maintain rate of climb or descent.

(c) When the desired altitude is reached, moving the vertical speed wheel to the detent disengages IAS hold. The pitch selector switch returns to the vertical speed position and altitude hold is engaged.

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(1) Yaw damping

(2) Constant altitude

(3) Coordinated turn

(4) Vertical speed

(5) Constant indicated airspeed or Mach number

(6) Pitch damping during turbulence

(7) Preselected compass heading

(8) Omnirange flying and localizer guidance

(9) ILS control

(10) Split-axes control

(11) Level off at preselected altitude.

B. Yaw Damper

(1) The yaw damper function can be engaged separately to provide necessary yaw damping during manual flying. Yaw damper control is not reflected at the rudder pedals.

C. Autopilot Control

(1) When the complete system is engaged, the autopilot controls the airplane in roll, pitch, and yaw axes. The existing attitude and directional reference is automatically maintained.

D. System Components (See Figure 1.)

Component	Function
(1) Autopilot Mode Annunciator	Provides visual display of radio guidance/approach mode controlling autopilot.
(2) Automatic Pilot Controller	Provides fingertip controls to enable the captain and first officer to engage the autopilot, select the various modes of operation, and to initiate maneuvering commands.
(3) Automatic Pilot Indicator	Provides visual indication of aileron and elevator servo drive trim conditions and output of yaw actuator position transducer. Lights indicate autopilot off, glide path armed, auto trim off.
(4) Autopilot Release Switches	Provide disengagement of the roll and pitch axes of the autopilot.
(5) Autopilot Servos (Split-Axes) Switches	Provide independent cutoff of yaw, roll, and pitch control functions.
(6) Accelerometers (six required)	Translate acceleration in yaw, roll, and pitch axes into electrical signels for damping short-period attitude changes.
(7) Servo Drives and Brackets (two required)	Initiate movement of the ailerons and elevator in response to amplified signals from the roll and pitch channels.
(8) Yaw Axis Electrohydraulic Transfer Valve (part of rudder hydraulic power package)	Provides the means for yaw channel input to the main control valve in the rudder hydraulic power package.
(9) Roll Channel Computer	Provides roll axis interlock; computes and shapes error and command signals to drive the aileron servo drive.

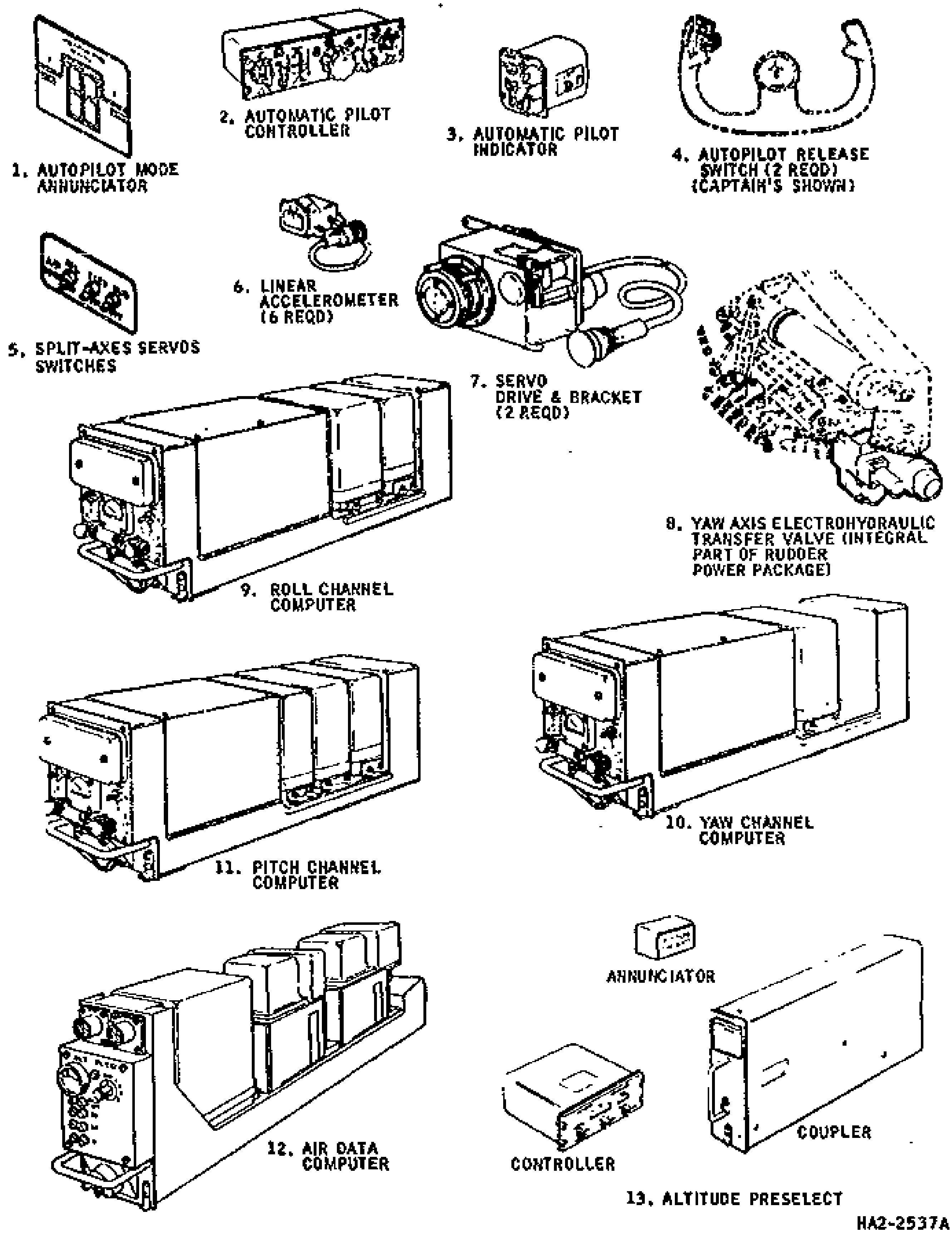
Component	Function
(10) Yaw Channel Computer	Provides automatic stability augmentation and turn coordination in response to command signals from the autopilot sensing and control devices.
(11) Pitch Channel Computer	Provides pitch axis interlock; computes and shapes error and command signals to drive the elevator servo drive.
(12) Air Data Computer	Provides signals for autopilot vertical speed, altitude hold, Mach Q_c/p data, airspeed (Q) switching of autopilot command parameters, and airspeed and Mach number data.
(13) Altitude Preselect (Coupler, Controller, and Annunciator)	Provides a means to program automatic level-off through the pitch axis when selected altitude is reached.

2. Operation

A. Yaw Axis

(1) Synchronization

(a) With yaw axis circuit breakers closed and power applied, the autopilot provides self-synchronization within the yaw channel computer. The synchronization provides a null output from the torquer amplifier to the rudder electrohydraulic transfer valve. With pitch and roll axes circuit breakers also closed, synchronization to airplane magnetic heading as sensed by the directional gyro is provided within the yaw channel computer by a heading synchronizer. The heading reference output signal is routed to the roll channel computer.



Autopilot System Components
Figure 1

(2) Yaw Damper

(a) The yaw damper mode is engaged when yaw axis ac and dc circuit breakers are closed and the servos engaged lever on the automatic pilot controller is moved to yaw damper position. The servos engage lever is held at the yaw damper position if all yaw axis engage path interlock requirements are met. The yaw channel computer provides rudder command signals to dampen the airplane dutch roll characteristics during manually and automatically controlled flight. Because of the rudder hydraulic and linkage tie-ins with the manual controls, yaw damper control actions are not reflected at th rudder pedals. Further, the pilot can maneuver the airplane in a normal manner through the rudder pedals with no opposing force or action from the yaw damper.

(b) With the autopilot 115-volt ac circuit breaker closed and the autopilot mode engaged, the yaw channel computer also provides rudder command signals to assist turn maneuvers.

(3) Autopilot

(a) The autopilot mode is engaged when yaw axis, pitch and roll axis, pilot, and air data circuit breakers are closed and the servos engage lever is set to autopilot. This continues yaw damper operation and also engages the roll and pitch axes. The yaw, roll, and pitch axes are series interlocked for autopilot control. When an interlock interruption occurs in any axis, the autopilot mode is automatically disengaged. If the pitch or roll axes are malfunctioning, the servos engage lever drops to yaw damper position and the autopilot off light on the automatic pilot indicator and autopilot legends on the captain's and first officer's navigation instrument failure warning annunciator panels flash red. The lights remain on until one of the autopilot release buttons or the annunciator reset button is pressed, or the autopilot is reengaged.

(b) During the approach phase of ILS operation, the yaw channel computer receives a roll command to rudder signal that compensates for long-term airplane heading asymmetries such as loss of an engine. In addition, a heading synchronizer in the yaw computer module receives heading signals from the directional gyro and provides heading reference and heading error data to the roll channel computer for heading hold functions.

B. Roll Axis

(1) Synchronization

(a) With pitch and roll circuit breakers closed and power applied, the autopilot provides continuous synchronization to airplane roll attitude and magnetic heading. This synchronization provides a null output from the aileron servo amplifier to the aileron servo drive motor.

(2) Roll Axis Engage

(a) The roll axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot position if all engage path interlock requirements are met.

(b) If the roll axis is engaged when the aircraft is at a roll angle up to 35 degrees, the airplane automatically returns smoothly to a wings-level condition. When the airplane roll angle reduces to less than 6 degrees, the autopilot automatically couples the airplane to the compass heading (compass system).

(c) Heading hold is initiated with the navigation selector switch on the automatic pilot controller at turn knob and the turn knob detent heading hold is automatically established when airplane bank angle is less than 6 degrees.

(d) Automatic disengagement of the autopilot mode occurs when the roll axis monitor detects a malfunction within the roll axis. The servos engage lever drops to yaw damper, and the autopilot off light comes on as an indication to the pilot. The other two axes may be operated by using the split-axes servo switches (see paragraph D).

(3) Turn Knob

(a) The turn knob, located on the automatic pilot controller, is the primary roll control mode. The knob provides a manual turn control function for changing airplane heading. The turn knob must be in detent to engage the autopilot.

(b) The turn knob operates through the roll axis (aileron channel) to establish and hold the desired bank angle required to initiate a heading change. The degree and direction of bank angle is proportional to the amount and direction of turn knob rotation. When the turn knob is moved from detent, the roll axis automatically decouples from the heading reference. As long as the turn knob is left out of detent, the airplane remains in a turn at the commanded bank angle. When the turn knob is returned to the detent position, the airplane returns to wings level and is recoupled to the heading reference which exists when bank angle becomes less than 6 degrees. Operation of the turn knob takes priority over any lateral control mode.

(4) Heading Select

(a) The heading select mode operates through the roll axis to establish and follow a chosen heading set on the course indicator or equivalent heading display. The heading select cursor on the indicator is positioned at the desired heading by using the heading select sync knob. With the navigation selector switch set to heading select, the airplane is automatically banked at a controlled roll rate up to a limited bank angle to execute a turn toward the selected heading. As this heading is approached, the airplane is smoothly brought to wings-level. The airplane is aligned with the selected heading and is directed to maintain that heading until new commands are given to the autopilot.

(5) Localizer/Omnirange

(a) The roll channel computer provides aileron control in response to lateral radio signals (VOR and ILS) if the navigation selector switch is rotated to LOC/VOR and the navigation receiver is tuned to the proper frequency. Desired omniradial heading or inbound runway heading must be set on the pictorial deviation indicator.

(b) Automatic beam capture is initiated by the pilot establishing an appropriate intercept heading, using either the turn knob or heading select mode. After the airplane rolls out on the intercept course, rotating the navigation selector switch to LOC/VOR establishes heading hold until lateral beam intercept.

(c) At beam intercept, the airplane turns toward the transmitting station at a limited bank angle that is a function of beam error, rate of change of beam error (ILS only), and course (runway) heading error. When the airplane attains the selected radial at beam center (on-course) the autopilot automatically integrates for crosswind correction. As the airplane approaches the zone-of-confusion above the VOR transmitter, interlocks decouple the beam signal, and the airplane is directed to fly at the drift-corrected radial heading. After passing the VOR station, the beam is again switched into roll command circuitry, and the autopilot tracks the outbound radial.

(d) The autopilot controller pitch selector switch and navigation selector switch move to the vertical speed and turn knob position, respectively, if the system monitoring and retraction technique (smart box) receives an invalid LOC/VOR signal.

(6) ILS

(a) With the navigation selector switch set to ILS at a specified beam error, glide path control is initiated. The pitch channel computer controls descent to glide path beam center while the roll channel computer maintains the airplane on beam center throughout the approach.

(b) Interlocks prevent selection of ILS unless the pitch axis is engaged and appropriate radio receiver is tuned to ILS frequency. The navigation selector switch will not hold in ILS, and glide path capture is prevented.

(7) Auxiliary Navigation Control (Optional)

The autopilot roll axis can provide automatic control in response to track error and cross-track deviation information received from an auxiliary navigation or inertial guidance system to maintain a selected ground track or sequency of ground tracks. Auxiliary navigation or inertial navigation is engaged by pressing and rotating the navigation selector switch to AUX NAV after setting the initial conditions in the auxiliary navigation or inertial controller. Upon engagement, the airplane is automatically turned to intercept auxiliary navigation track.

C. Pitch Axis

(1) Synchronization

(a) With pitch and roll circuit breakers closed and power applied, the autopilot provides continuous synchronization of airplane pitch attitude, vertical speed, and altitude. This synchronization provides a null output from the elevator servo amplifier to the elevator servo drive motor prior to engagement.

(2) Pitch Axis Engage

(a) The pitch axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot if all engage path interlock requirements are met.

(b) When engaged, the pitch axis provides a vertical speed hold function. This is the primary pitch control mode. This mode adjusts the pitch attitude of the airplane to maintain the vertical speed existing when the pitch axis was engaged. The vertical speed hold function continues until changed by use of the vertical speed wheel on the automatic pilot controller.

(c) Automatic disengagement of autopilot control occurs when the pitch axis monitor detects a malfunction within the pitch axis. The servos engage lever drops to yaw damper and the autopilot off light comes on as an indication to the pilot. The remaining two axes may be operated by using the split-axes servo switches (see paragraph D).

(3) Vertical Speed Control

(a) The detent (center) position of the vertical speed wheel is altitude hold (zero vertical speed). During synchronization, the motor-driven vertical speed wheel follows up to the vertical speed of the airplane, providing a vertical speed reference for the vertical speed hold function at engagement.

(b) When the vertical speed wheel is moved out of detent, the airplane assumes (and adjusts as required) a pitch attitude to hold the commanded vertical speed. The pilot observes the rate of climb or descent on the vertical speed indicator and manually adjusts the vertical speed wheel to obtain the desired vertical speed. The pitch selector switch returns to vertical speed when the vertical speed wheel is manually moved. The navigation selector switch returns to turn knob when the airplane is under glide path control mode if the vertical speed knob is manually moved. If the system is in the glide path extension mode, and was manually or automatically engaged to this mode, manual movement of the vertical speed wheel reverts the system to the turn knob and/or vertical speed modes.

(4) Altitude Hold

(a) Altitude hold is established when the vertical speed wheel is at altitude hold (zero vertical speed). The airplane altitude existing when the vertical speed wheel is returned to the detent (altitude hold) position is maintained until a change in vertical speed is commanded.

(5) Pitch Damp

(a) When the pitch selector switch is pressed and rotated to the pitch damp position, the pitch damp mode is initiated. During this mode, which is used for turbulence penetration, automatic pitch trim is disconnected. Pitch trim is accomplished by manual actuation of the horizontal stabilizer controls. A "soft" pitch attitude damping function is provided by the autopilot to minimize pitch rate deviations. The pitch and roll monitors (automatic cutoff) are bypassed during pitch damp mode operation.

(6) Glide Path Control - Automatic

(a) The autopilot pitch axis provides automatic glide path control from signals received from a glide path receiver. The system automatically captures the glide path beam when the pitch axis is engaged, the glide path receiver is tuned to an ILS frequency, and the navigation selector switch is at ILS. At glide path capture, the pitch selector switch returns to vertical speed if the switch was at another position.

(b) A 10-second capture period begins at glide path capture. During this period, a fixed vertical speed command is applied to the pitch channel compute , causing the airplane to descend at approximately 700 feet per minute. The vertical speed wheel follows up to this commanded rate of descent.

(c) After the 10-second capture period terminates, the airplane is in the glide path control phase. In this phase, the airplane follows the glide path beam.

(d) The vertical speed wheel follows up to the rate of descent during the control phase. Heading, localizer, and glide path gain programing are initiated as a function of radio altimeter altitude (analog dc output). If the radio altimeter malfunctions, localizer and glide path gains are programmed at glide path capture to compensate for ILS beam convergence. The control phase ends when the pilot terminates the automatic approach to land the airplane manually.

(7) Glide Path Extension - Manual

The glide path extension mode is manually engaged by placing the pitch selector at G/P EXT. This mode can be used by the pilot to initiate glide path second-stage gain programming only when glide path is energized (capture +10 seconds), the radio altimeter has failed or is not connected to the autopilot, and the middle marker beacon is not passed. If the radio altimeter is disabled or not installed, glide path gains are second-stage programmed automatically upon interception of the middle marker beacon.

(8) IAS Hold

(a) The IAS (indicated airspeed) hold mode is engaged by moving the pitch selector switch to the IAS hold position. The indicated airspeed existing at the time of engagement is maintained by automatic adjustment of the airplane pitch attitude.

(b) With the pitch axis engaged, the vertical speed hold function automatically controls vertical speed. When the desired indicated airspeed is attained, the pitch selector switch is rotated to the IAS hold position. Automatic elevator control adjusts pitch attitude to maintain the desired airspeed; throttle adjustment will maintain rate of climb or descent.

(c) When the desired altitude is reached, moving the vertical speed wheel to the detent disengages IAS hold. The pitch selector switch returns to the vertical speed position and altitude hold is engaged.

(9) Mach Hold

(a) The Mach hold mode is engaged by moving the pitch selector switch to the Mach hold position. The Mach number existing at the time of engagement is maintained by automatic adjustment of the airplane pitch attitude. As the airplane climbs at a constant speed, the Mach number increases with altitude. When the desired Mach number is attained, the pitch selector switch is pressed and rotated to the Mach hold position. The airplane then climbs at a decreasing airspeed to maintain the desired Mach number. Moving the vertical speed wheel to the detent disengages the Mach hold mode. The pitch selector switch returns to the vertical speed position and the altitude hold mode is engaged.

D. Split-Axes Operation

(1) The three autopilot (split-axes) servo switches, located on the captain's instrument panel provide independent cutoff of roll, pitch, and yaw control functions of the autopilot. In this manner, the pilot may use manual control in one or two axes while the autopilot retains control in the remaining engaged axes. In addition, even though a malfunction occurs in one or more control channels, a portion of the autopilot may still be used. Split-axes operation also provides approach operation with manual pitch axis control.

(2) The roll and pitch channels can be split off individually, but the yaw channel cannot. If the yaw channel is to be split off, both rudder and aileron servo switches must be placed in their off positions. This interlock is necessary due to roll channel dependence on yaw damper for proper performance.

(3) For LOC/VOR operation with the pitch axis split off, localizer gain programming is initiated at interception of the outer marker beacon.

E. Level-Off at Preselected Altitude

(1) The altitude preselect system provides a means to program selected altitude into the autopilot for automatic level-off when desired altitude is reached. In addition, when flying manually, the system indicates by annunciator lights when manual level-off should be initiated. Altitude preselect consists of a panel-mounted controller, two altitude preselect annunciator lights, and an altitude preselect coupler.

AUTOPILOT - DESCRIPTION AND OPERATION

1. Description

A. The autopilot is that portion of the auto flight control system which operates the flight control surfaces of the airplane as needed to maintain straight and level flight or maneuver in response to pilot commands. Operating modes can be selected to provide automatic control of:

(1) Yaw damping

(2) Constant altitude

(3) Coordinated turn

(4) Vertical speed

(5) Pitch damping during turbulence

(6) Preselected compass heading

(7) Omnirange flying and localizer guidance

(8) ILS control

(9) Split-axes control

B. Yaw Damper

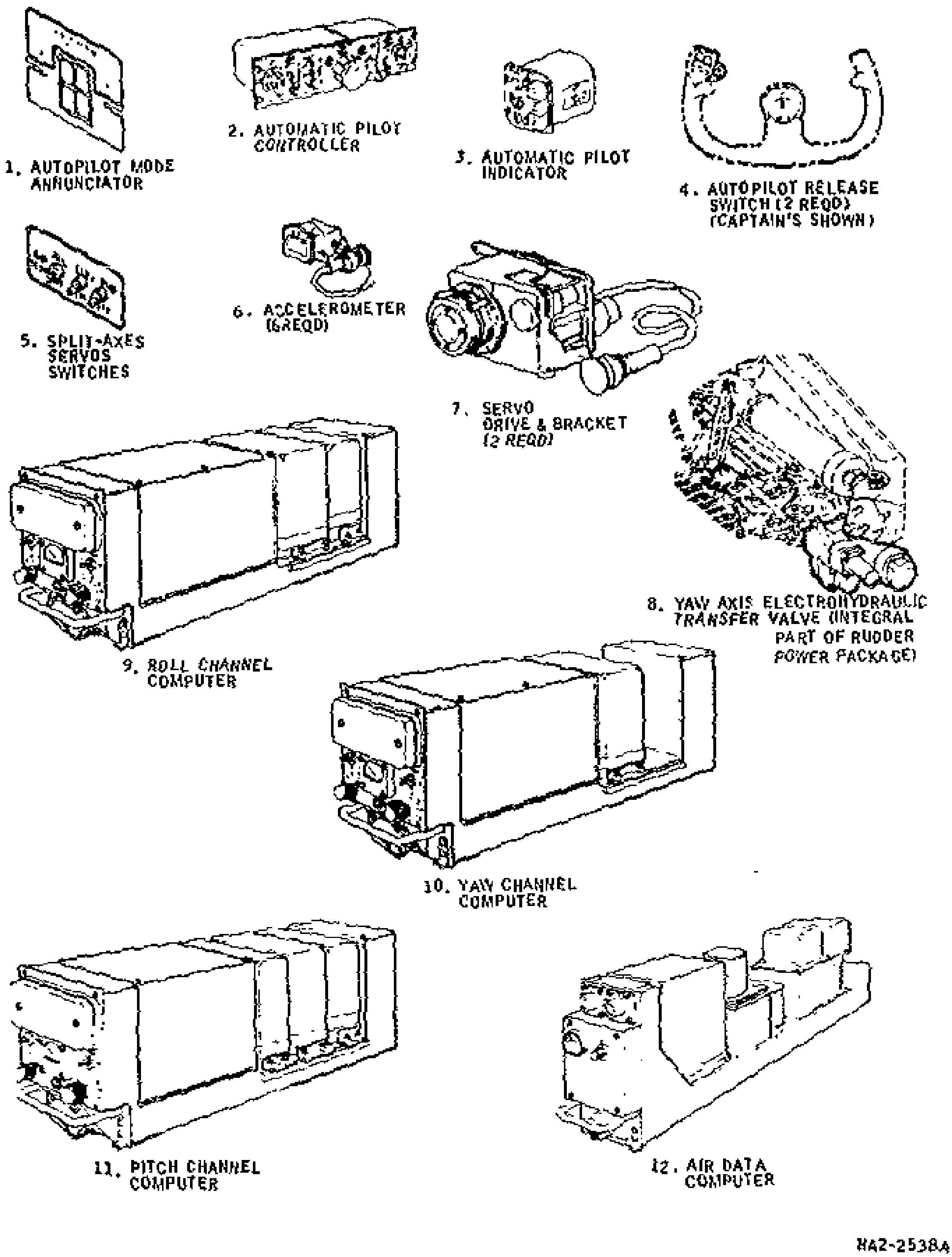
(1) The yaw damper function can be engaged separately to provide necessary yaw damping during manual flying. Yaw damper control is not reflected at the rudder pedals.

C. Autopilot Control

(1) When the complete system is engaged, the autopilot controls the airplane in roll, pitch, and yaw axes. The existing attitude and directional reference is automatically maintained.

D. System Components (See Figure 1.)

Component	Function
(1) Autopilot Mode Annunciator	Provides visual display of radio guidance/approach mode controlling autopilot.



Autopilot System Components
Figure 1

Component	Function
(2) Automatic Pilot Controller	Provides fingertip controls to enable the captain and first officer to engage the autopilot, select the various modes of operation, and to initiate maneuvering commands.
(3) Automatic Pilot Indicator	Provides visual indication of aileron and elevator servo drive trim conditions and output of yaw actuator position transducer. Lights indicate autopilot off, glide path armed, auto trim off.
(4) Autopilot Release Switches	Provide disengagement of the roll and pitch axes of the autopilot.
(5) Autopilot Servos (Split-Axes) Switches	Provide independent cutoff of yaw, roll, and pitch control functions.
(6) Accelerometers (six required)	Translate acceleration in yaw, roll, and pitch axes into electrical signals for damping short-period attitude changes.
(7) Servo Drives and Brackets (two required)	Initiate movement of the ailerons and elevator in response to amplified signals from the roll and pitch channels.
(8) Yaw Axis Electrohydraulic Transfer Valve (part of rudder hydraulic power package)	Provides the means for yaw channel input to the main control valve in the rudder hydraulic power package.
(9) Roll Channel Computer	Provides roll axis interlock; computes and shapes error and command signals to drive the aileron servo drive.
(10) Yaw Channel Computer	Provides automatic stability augmentation and turn coordination in response to command signals from the autopilot sensing and control devices.

Component	Function
(11) Pitch Channel Computer	Provides pitch axis interlock; computes and shapes error and command signals to drive the elevator servo drive.
(12) Air Data Computer	Provides signals for autopilot vertical speed, altitude hold, Mach Q_c/p data, and airspeed (Q) switching of autopilot command parameters.

2. Operation

A. Yaw Axis Modes of Operation

(1) Synchronization

(a) With yaw axis circuit breakers closed and power applied, the autopilot provides self-synchronization within the yaw channel computer. The synchronization provides a null output from the torquer amplifier to the rudder electrohydraulic transfer valve. With pitch and roll axes circuit breakers also closed, synchronization to airplane magnetic heading as sensed by the directional gyro is provided within the yaw channel computer by a heading synchronizer. The heading reference output signal is routed to the roll channel computer.

(2) Yaw Damper

(a) The yaw damper mode is engaged when yaw axis ac and dc circuit breakers are closed and the servos engage lever on the automatic pilot controller is moved to yaw damper position. The servos engage lever is held at the yaw damper position if all yaw axis engage path interlock requirements are met. The yaw channel computer provides rudder command signals to dampen the airplane dutch roll characteristics during manually and automatically controlled flight. Because of the rudder hydraulic and linkage tie-ins with the manual controls, automatic yaw damper control actions are not reflected at the rudder pedals. Further, the pilot can maneuver the airplane in a normal manner through the rudder pedals with no opposing force or action from the yaw damper.

(b) With the autopilot 115-volt ac circuit breaker closed and the autopilot mode engaged, the yaw channel computer also provides rudder command signals to assist turn maneuvers.

(3) Autopilot

(a) The autopilot mode is engaged when yaw axis, pitch and roll axes, and air data circuit breakers are closed and the servos engage lever is set at autopilot. This continues yaw damper operation and also engages the roll and pitch axes. The yaw, roll, and pitch axes are series interlocked for autopilot control. When an interlock interruption occurs in any axis the autopilot mode is automatically disengaged. If the pitch or roll axis is malfunctioning, the servos engage lever drops to yaw damper position, and the autopilot off light comes on as an indication to the pilot. The light remains on until one of the autopilot release buttons is pressed.

(b) During the approach phase of ILS operation, the yaw channel computer receives a roll command to rudder signal that compensates for long-term airplane heading asymmetries such as loss of an engine. In addition, a heading synchronizer in the yaw computer module receives heading signals from the directional gyro and provides heading reference and heading error data to the roll channel computer for heading hold functions.

B. Roll Axis

(1) Synchronization

(a) With pitch and roll axes circuit breakers closed and power applied, the autopilot provides continuous synchronization to airplane roll attitude and magnetic heading. This synchronization provides a null output from the aileron servo amplifier to the aileron servo drive motor.

(2) Roll Axis Engage

(a) The roll axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot position if all engage path interlock requirements are met.

(b) If the roll axis is engaged when the aircraft is at a roll angle up to 35 degrees, the airplane automatically returns smoothly to a wings-level condition. When the airplane roll angle reduces to less than 6 degrees, the autopilot automatically couples the airplane to the compass heading (compass system).

(c) Heading hold is initiated with the navigation selector switch on the automatic pilot controller at turn knob and the turn knob at detent, heading hold is automatically established when airplane bank angle is less than 6 degrees.

(d) Automatic disengagement of the autopilot mode occurs when the roll axis monitor detects a malfunction within the roll axis. The servos engage lever drops to yaw damper, and the autopilot off light comes on as an indication to the pilot. The yaw or pitch axes may be operated by using the split-axes servo switches (see paragraph D).

(3) Turn Knob

(a) The turn knob located on the automatic pilot controller is the primary roll control mode. The turn knob provides a manual turn control function for changing airplane heading. The turn knob must be in detent position to engagement of the autopilot.

(b) The turn knob operates through the roll axis (aileron channel) to establish and hold the desired bank angle required to initiate a heading change. The degree and direction of bank angle is proportional to the amount and direction of turn knob rotation. When the turn knob is moved from detent, the roll axis automatically decouples from the heading reference. As long as the turn knob is left out of detent, the airplane remains in a turn at the commanded bank angle. When the turn knob is returned to detent, the airplane returns to wings level and is recoupled to the heading reference which exists when bank angle becomes less than 6 degrees. Operation of the turn knob takes priority over any lateral control mode.

(4) Heading Select

(a) The heading select mode operates through the roll axis to establish and follow a chosen heading set on the course indicator or equivalent heading display. The heading select cursor on the indicator is positioned at the desired heading by using the heading select sync knob. With the navigation selector switch set to heading select, the airplane is automatically banked at a controlled roll rate up to a limited bank angle to execute a turn toward the selected heading. As this heading is approached, the airplane is smoothly brought to wings-level. The airplane is aligned with the selected heading and is directed to maintain that heading until new commands are given to the autopilot.

(5) Localizer/Omnirange

(a) The roll channel computer provides aileron control in response to lateral radio signals (VOR and ILS) if the navigation selector switch is rotated to LOC/VOR and the navigation receiver is tuned to the proper frequency. Desired omniradial heading or inbound runway heading must be set on the pictorial deviation indicator.

(b) Automatic beam capture is initiated by the pilot establishing an appropriate intercept heading by using either the turn knob or heading select mode. After the airplane rolls out on the intercept course, rotating the navigation selector switch to LOC/VOR establishes heading hold until lateral beam intercept.

(c) At beam intercept, the airplane turns toward the transmitting station at a limited bank angle that is a function of beam error, rate of change of beam error (ILS only), and course (runway) heading error. When the airplane attains the selected radial at beam center (on-course) the autopilot automatically integrates for crosswind correction. As the airplane approaches the zone-of-confusion above the VOR transmitter, interlocks decouple the beam signal, and the airplane is directed to fly at the drift-corrected radial heading. After passing the VOR station, the beam is again switched into roll command circuitry, and the autopilot tracks the outbound radial.

(6) ILS

(a) With the navigation selector switch set to ILS at a specified beam error, glide path control is initiated. The pitch channel computer controls descent to glide path beam center localizer while the roll channel computer maintains the airplane on beam center to minimum altitude or disengagement.

(b) Interlocks prevent selection of ILS unless the pitch axis is engaged and appropriate radio receiver is tuned to ILS frequency. The navigation selector switch will not hold in ILS, and glide path capture is prevented.

(7) Auxiliary Navigation Control (optional)

(a) The autopilot roll axis can provide automatic control in response to track error and cross-track deviation information received from an auxiliary navigation system to maintain a selected ground track or sequence of ground tracks. Auxiliary navigation is engaged by pressing and rotating the navigation selector switch to AUX NAV after setting the initial conditions in the auxiliary navigation controller. Upon engagement, the airplane is automatically turned to intercept auxiliary navigation. Auxiliary navigation control of the airplane is implemented only in airplanes equipped with auxiliary navigation system.

C. Pitch Axis

(1) Synchronization

(a) With pitch and roll axes circuit breakers closed and power applied, the autopilot provides continuous synchronization to airplane pitch attitude, vertical speed, and altitude. This synchronization provides a null output from the elevator servo amplifier to the elevator servo drive motor prior to engagement.

(2) Pitch Axis Engage

(a) The pitch axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot if all engage path interlock requirements are met.

(b) When engaged, the pitch axis provides a vertical speed hold function. This is the primary pitch control mode. This mode adjusts the pitch attitude of the airplane to maintain the vertical speed existing when the pitch axis was engaged. The vertical speed hold function continues until changed by use of the vertical speed wheel on the automatic pilot controller.

(c) Automatic disengagement of autopilot control occurs when the pitch axis monitor detects a malfunction within the pitch axis. The servos engage lever drops to yaw damper and the autopilot off light comes on as an indication to the pilot. The yaw and roll axis may be operated by using the split-axes servo switches (see paragraph D).

(3) Vertical Speed Control

(a) The detent (center) position of the vertical speed wheel is altitude hold (zero vertical speed). During synchronization, the motor-driven vertical speed wheel follows up to the vertical speed of the airplane, providing a vertical speed reference for the vertical speed hold function at engagement.

(b) When the vertical speed wheel is moved out of detent, the airplane assumes (and adjusts as required) a pitch attitude to hold the commanded vertical speed. The pilot observes the rate of climb or descent on the vertical speed indicator and manually adjusts the vertical speed wheel to obtain the desired vertical speed. The pitch selector switch returns to vertical speed when the vertical speed wheel is manually moved. The navigation selector switch returns to turn knob when the airplane is under glide path control mode if the vertical speed knob is manually moved. If the system is in the glide path extension mode and was manually or automatically engaged to this mode, manual movement of the vertical speed wheel reverts the system to the turn knob and/or vertical speed modes.

(4) Altitude Hold

(a) Altitude hold is established when the vertical speed wheel is at altitude hold (zero vertical speed). The airplane altitude existing when the vertical speed wheel is returned to the detent (altitude hold) position is maintained until a change in vertical speed is commanded.

(5) Pitch Damp

(a) When the pitch selector switch is pressed and rotated to the pitch damp position, the pitch damp mode is initiated. During this mode, which is used for turbulence penetration, automatic pitch elevator trim is disconnected. Pitch trim is accomplished by manual actuation of the horizontal stabilizer controls. A "soft" pitch attitude clamp function is provided by the autopilot to minimize pitch rate deviations. There is no vertical gyro pitch attitude reference during operation of pitch damp mode.

(6) Glide Path Control - Automatic

(a) The autopilot pitch axis provides automatic glide path control from signals received from a glide path receiver. The system automatically captures the glide path beam when the pitch axis is engaged, the glide path receiver is tuned to an ILS frequency, and the navigation selector switch is at ILS. At glide path capture the pitch selector switch returns to vertical speed if the switch was at another position.

(b) A 10-second capture period begins at glide path capture. During this period, a fixed vertical speed command is applied to the pitch channel computer, causing the airplane to descend at approximately 700 feet per minute. The vertical speed wheel follows up to this commanded rate of descent.

(c) After the 10-second capture period terminates, the airplane is in the glide path control phase. In this phase, the airplane follows the glide path beam.

(d) The vertical speed wheel follows up to the rate of descent during the control phase. Heading, localizer, and glide path gain programming are initiated as a function of radio altimeter altitude (analog dc output). If the radio altimeter malfunctions, localizer and glide path gains are programmed at glide path capture to compensate for ILS beam convergence. The control phase ends when the pilot terminates the automatic approach to land the airplane manually.

(7) Glide Path Extension - Manual

(a) The glide path extension mode is manually engaged by placing the pitch selector switch at G/P EXT. This mode can be used by the pilot to initiate glide path second-stage gain programming only when glide path is energized (capture +10 seconds), the radio altimeter has failed or is not connected to the autopilot, and the middle marker beacon is not passed. If the radio altimeter is disabled or not installed, glide path gains are second-stage programmed automatically upon interception of the middle marker beacon.

D. Split-Axes Operation

(1) The three autopilot (split-axes) servo switches, located on the flight instrument panel, provide independent cut-off of roll, pitch, and yaw control functions of the autopilot. In this manner, the pilot may use manual control in one or two axes while the autopilot retains control of the remaining engaged axes. In addition, even though a malfunction occurs in one or more control channels a portion of the autopilot may still be used. Split-axes operation also provides approach operation with manual pitch axis control.

(2) The roll and pitch channels may be split off individually, but the yaw channel may not. If the yaw channel is to be split off, both rudder and aileron servo switches must be placed in their off position. This is necessary due to roll channel dependence on yaw damper for proper performance.

NOTE: The SPLIT AXIS light will come on only when one or more of the axes are split off while the servos engage lever is in the AUTOPILOT POSITION.

AUTOPILOT - DESCRIPTION AND OPERATION

1. Description

A. The autopilot is that portion of the auto flight control system which operates the flight control surfaces of the airplane as needed to maintain straight and level flight or to maneuver in response to pilot commands. Operating modes can be selected to provide automatic control of:

(1) Yaw damping

(2) Constant altitude

(3) Coordinated turn

(4) Vertical speed

(5) Pitch damping during turbulence

(6) Preselected compass heading

(7) Omnirange flying and localizer guidance

(8) ILS control.

B. Yaw Damper

(1) The yaw damper function can be engaged separately to provide necessary yaw damping during manual flying. Yaw damper control is not reflected at the rudder pedals.

C. Autopilot Control

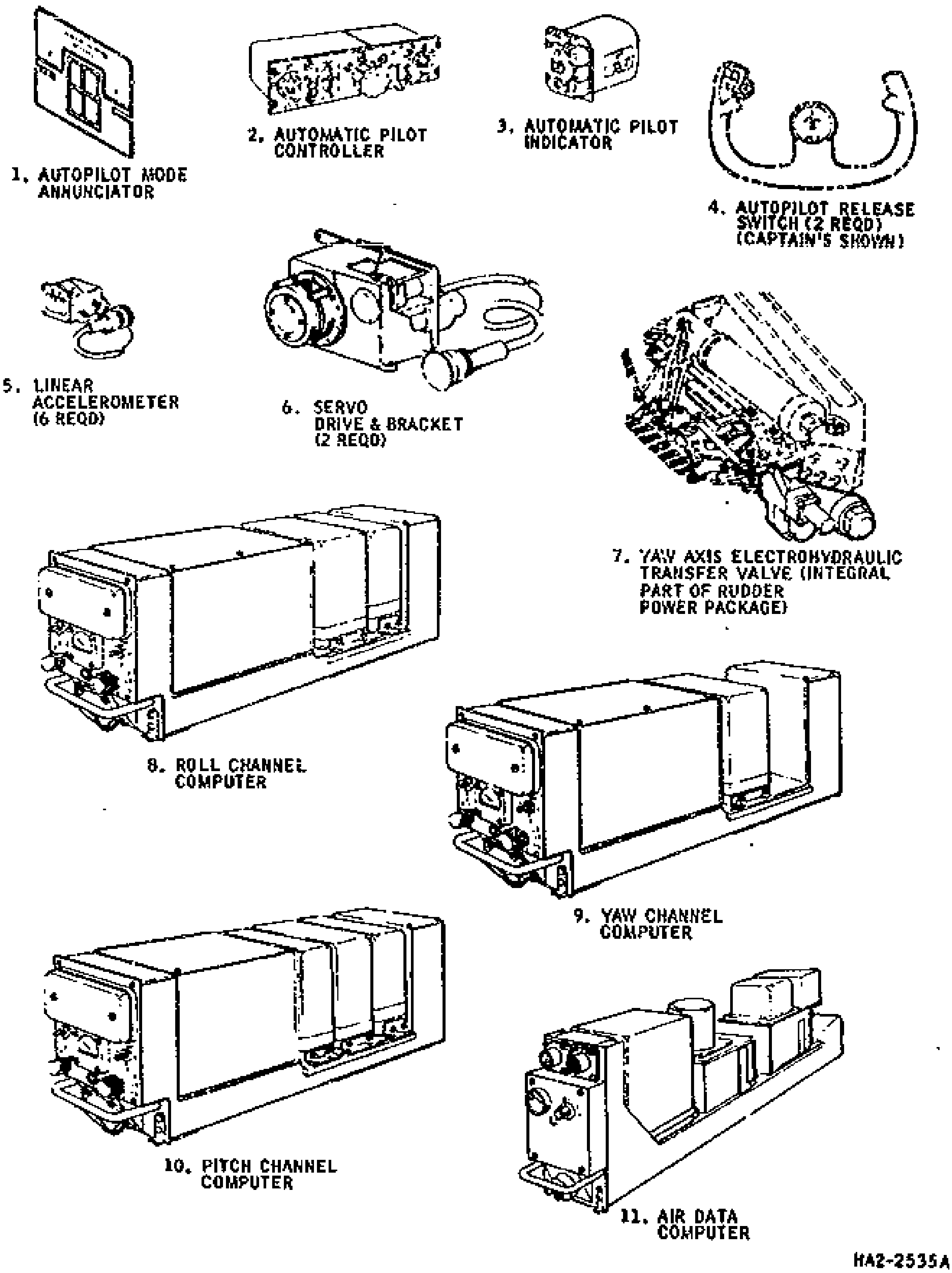
(1) When the complete system is engaged, the autopilot controls the airplane in roll, pitch, and yaw axes. The existing attitude and directional reference is automatically maintained.

D. System Components (See Figure 1.)

Component	Function
1. Autopilot Mode Annunciator	Provides visual display of radio guidance/approach mode controlling autopilot.

	Component	Function
(2)	Automatic Pilot Controller	Provides fingertip controls to enable the captain and first officer to engage the autopilot, select the various modes of operation, and to initiate maneuvering commands. A switch provides means to transfer control between captain's and first officer's navigation instruments.
(3)	Automatic Pilot Indicator	Provides visual indication of trim conditions aileron and elevator servo drive and output of yaw actuator position transducer. Lights indicate autopilot off, glide path armed, auto trim off.
(4)	Autopilot Release Switches	Provide disengagement of the roll and pitch axes of the autopilot.
(5)	Accelerometers (six required)	Translate acceleration in yaw, roll, and pitch axes into electrical signals for damping short-period attitude changes.
(6)	Servo Drives and Brackets	Initiate movement of the ailerons and elevator in response to amplified signals from the roll and pitch channels.
(7)	Yaw Axis Electrohydraulic Transfer Valve (part of rudder hydraulic power package)	Provides the means for yaw channel input to the main control valve in the rudder hydraulic power package.
(8)	Roll Channel Computer	Provides roll axis interlock; computes and shapes error and command signals to drive the aileron servo drive.
(9)	Yaw Channel Computer	Provides automatic stability augmentation and turn coordination in response to command signals from the autopilot sensing and control devices.

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Autopilot System Components
Figure 1

Component	Function
(10) Pitch Channel Computer	Provides pitch axis interlock; computes and shapes error and command signals to drive the elevator servo drive.
(11) Air Data Computer	Provides signals for autopilot vertical speed, altitude hold, Mach Q/p data, and airspeed (Q) switching of autopilot command parameters.

2. Operation

A. Yaw Axis

(1) Synchronization

(a) With yaw axis circuit breakers closed and power applied, the autopilot provides self-synchronization within the yaw channel computer. The synchronization provides a null output from the torquer amplifier to the rudder electrohydraulic transfer valve. With pitch and roll axis circuit breakers also closed, synchronization to airplane magnetic heading, as sensed by the directional gyro, is provided within the yaw channel computer by a heading synchronizer. The heading reference output signal is routed to the roll channel computer.

(2) Yaw Damper

(a) The yaw damper mode is engaged when yaw axis ac and dc circuit breakers are closed and the servos engage lever on the automatic pilot controller is moved to yaw damper position. The servos engage lever is held at the yaw damper position if all yaw axis engage path interlock requirements are met. The yaw channel computer provides rudder command signals to dampen the airplane dutch roll characteristics during manually and automatically controlled flight. Because of the rudder hydraulic and linkage tie-ins with the manual controls, yaw damper control actions are not reflected at the rudder pedals. Further, the pilot can maneuver the airplane in a normal manner through the rudder pedals with no opposing force or action from the yaw damper.

(b) With the pitch and roll axes 115-volt circuit breaker closed, and the autopilot mode engaged , the yaw channel computer also provides rudder command signals to assist turn maneuvers.

(3) Autopilot

(a) The autopilot mode is engaged when yaw axis, pitch and roll axes, and air data circuit breakers are closed and the servos engage lever

is set at autopilot. This continues yaw damper operation and also engages the roll and pitch axes. The yaw, roll, and pitch axes are series interlocked for autopilot control. When an interlock interruption occurs in any axis, the autopilot mode is automatically disengaged. If the pitch or roll axis is malfunctioning, the servos engage lever drops to yaw damper position, and the autopilot off light comes on as an indication to the pilot. The light remains on until one of the autopilot release buttons is pressed.

(b) During the approach phase of ILS operation, the yaw channel computer receives a roll command to rudder signal that compensates for long-term airplane heading asymmetries such as loss of an engine. In addition, a heading synchronizer in the yaw computer module receives heading signals from the directional gyro and provides heading reference and heading error data to the roll channel computer for heading hold functions.

B. Roll Axis

(1) Synchronization

(a) With pitch and roll circuit breakers closed and power applied, the autopilot provides continuous synchronization to airplane roll attitude and magnetic heading. This synchronization provides a null output from the aileron servo amplifier to the aileron servo drive motor.

(2) Roll Axis Engage

(a) The roll axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot position if all engage path interlock requirements are met. The yaw, roll, and pitch axes are series-interlocked.

(b) If the roll axis is engaged when the aircraft is at a roll angle (up to 35 degrees), the airplane automatically returns smoothly to a wings-level condition. When the airplane roll angle reduces to less than 6 degrees, the autopilot automatically couples the airplane to the compass heading (compass system).

(c) Heading hold is initiated with the navigation selector switch on the automatic pilot controller at turn knob and the turn knob at detent, heading hold is automatically established when airplane bank angle is less than 6 degrees.

(d) Automatic disengagement of the autopilot mode occurs when the roll axis monitor detects a malfunction within the roll axis. The servos engage lever drops to yaw damper, and the autopilot off light comes on as an indication to the pilot.

(3) Turn Knob

(a) The turn knob, located on the automatic pilot controller, is the primary roll control mode. The knob provides a manual turn control function for changing airplane heading. The turn knob must be in detent to engage the autopilot.

(b) The turn knob operates through the roll axis (aileron channel) to establish and hold the desired bank angle required to initiate a heading change. The degree and direction of bank angle is proportional to the amount and direction of turn knob rotation. When the turn knob is moved from detent, the roll axis automatically decouples from the heading reference. As long as the turn knob is left out of detent, the airplane remains in a turn at the commanded bank angle. When the turn knob is returned to detent, the airplane returns to wings level and is reccupled to the heading reference which exists when bank angle becomes less than 6 degrees. Operation of the turn knob takes priority over any roll control mode.

(4) Heading Select

(a) The heading select mode operates through the roll axis to establish and follow a chosen heading set on the course indicator or equivalent heading display. The heading select cursor on the indicator is positioned at the desired heading by using the heading select synchronization knob. With the navigation selector switch set to heading select, the airplane is automatically banked at a controlled roll rate up to a limited bank angle to execute a turn toward the selected heading. As this heading is approached, the airplane is smoothly brought to wings-level. The airplane is aligned with the selected heading and is directed to maintain that heading until new commands are given to the autopilot.

(5) Localizer/Omnirange

(a) The roll channel computer provides aileron control in response to lateral radio signals (VOR and ILS) if the navigation selector switch is rotated to LOC/VOR and the navigation receiver is tuned to the proper frequency. Desired omniradial heading or inbound runway heading must be set on the pictorial deviation indicator.

(b) Automatic beam capture is initiated by the pilot establishing an approach intercept heading, using either the turn knob or heading select mode. After the airplane rolls out on the intercept course, rotating the navigation selector switch to LOC/VOR establishes heading hold until lateral beam intercept.

(c) At beam intercept, the airplane turns toward the transmitting station at a limited bank angle that is a function of beam error, rate of change of beam error (ILS only), and course runway heading error. When the airplane attains the selected radial at beam center (on-course) the autopilot automatically integrates for crosswind correction. As the airplane approaches the zone-of-confusion above the VOR transmitter, interlocks decouple the beam signal, and the airplane is directed to fly at the drift-corrected radial heading. After passing the VOR station, the beam is again switched into roll command circuitry, and the autopilot tracks the out-bound radial.

(6) ILS

(a) With the navigation selector switch set to ILS at a specified beam error, glide path control is initiated. The pitch channel computer controls descent to glide path beam center while the roll channel computer maintains the airplane on localizer beam center to minimum altitude or disengagement.

(b) Interlocks prevent selection of ILS unless the pitch axis is engaged and appropriate radio receiver is tuned to ILS frequency. The navigation selector switch will not hold in ILS, and glide path capture is prevented.

(7) Auxiliary Navigation Control (Optional)

(a) The autopilot roll axis can provide automatic control in response to track error and cross track deviation information received from an auxiliary navigation system to maintain a selected ground track or sequence of ground tracks. Auxiliary navigation is engaged by pressing and rotating the navigation selector switch to AUX NAV after setting the initial conditions in the auxiliary navigation controller. Upon engagement, the airplane is automatically turned to intercept auxiliary navigation track. Auxiliary navigation control of the airplane is implemented only in airplanes equipped with auxiliary navigation systems.

C. Pitch Axis

(1) Synchronization

(a) With pitch and roll axes circuit breakers closed and power applied, the autopilot provides continuous synchronization of airplane pitch attitude, vertical speed, and altitude. This synchronization provides a null output from the elevator servo amplifier to the elevator servo drive motor prior to engagement.

(2) Pitch Axis Engage

(a) The pitch axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot if all engage path interlock requirements

are met.

(b) When engaged, the pitch axis provides a vertical speed hold function. This is the primary pitch control mode. This mode adjusts the pitch attitude of the airplane to maintain the vertical speed existing when the pitch axis was engaged. The vertical speed hold function continues until changed by use of the vertical speed wheel on the automatic pilot controller.

(c) Automatic disengagement of autopilot control occurs when the pitch axis monitor detects a malfunction within the pitch axis. The servos engage lever drops to yaw damper and the autopilot off light comes on as an indication to the pilot.

(3) Vertical Speed Control

(a) The detent (center) position of the vertical speed wheel is altitude hold (zero vertical speed). During synchronization, the motor-driven vertical speed wheel follows up to the vertical speed of the airplane, providing a vertical speed reference for the vertical speed hold function at engagement.

(b) When the vertical speed wheel is moved out of detent, the airplane assumes (and adjusts as required) a pitch attitude to hold the commanded vertical speed. The pilot observes the rate of climb or descent on the vertical speed indicator and manually adjusts the vertical speed wheel to obtain the desired vertical speed. The pitch selector switch returns to vertical speed when the vertical speed wheel is manually moved. The navigation selector switch returns to turn knob when the airplane is under glide path control mode if the vertical speed knob is manually moved. If the system is in the glide path extension mode and was manually or automatically engaged to this mode, manual movement of the vertical speed wheel reverts the system to the turn knob and/or vertical speed modes.

(4) Altitude Hold

(a) Altitude hold is established when the vertical speed wheel is at altitude hold (zero vertical speed). The airplane altitude existing when the vertical speed wheel is returned to detent (altitude hold) is maintained until a change in vertical speed is commanded.

(5) Pitch Damp

(a) When the pitch selector switch is pressed and rotated to the pitch damp position, the pitch damp mode is initiated. During this mode, which is used for turbulence penetration, automatic pitch trim is disconnected. Pitch trim is accomplished by manual actuation of

the horizontal stabilizer controls. A "soft" pitch attitude damping function is provided by the autopilot to minimize pitch rate deviations. There is no vertical gyro pitch attitude reference during pitch damp mode operation.

(6) Glide Path Control - Automatic

(a) The autopilot pitch axis provides automatic glide path control from signals received from a glide path receiver. The system automatically captures the glide path beam when the pitch axis is engaged, the glide path receiver is tuned to an ILS frequency, and the navigation selector switch is at ILS. At glide path capture the pitch selector switch returns to vertical speed if the switch was at another position.

(b) A 10-second capture period begins at glide path capture. During this period, a fixed vertical speed command is applied to the pitch channel computer, causing the airplane to descend at approximately 700 feet per minute. The vertical speed wheel follows up to this commanded rate of descent.

(c) After the 10-second capture period terminates, the airplane is in the glide path control phase. In this phase, the airplane follows the glide path beam.

(d) The vertical speed wheel follows up to the rate of descent during the control phase. Heading, localizer, and glide path gain programming are initiated as a function of radio altimeter altitude (analog dc output). If the radio altimeter malfunctions, localizer and glide path gains are programmed at glide path capture to compensate for ILS beam convergence. The control phase ends when the pilot terminates the automatic approach to land the airplane manually.

(7) Glide Path Extension

(a) The glide path extension mode is manually engaged by placing the pitch selector switch at G/P EXT. This mode can be used by the pilot to initiate glide path second-stage gain programming only when glide path is energized (capture + 10 seconds), the radio altimeter has failed or is not connected to the autopilot, and the middle marker beacon is not passed. If the radio altimeter is disabled or not installed, glide path gains are second-stage programmed automatically upon interception of middle marker beacon.

(8) Navigation Transfer

(a) A visual display on the instrument panel shows whether captain's or first officer's navigation instruments are supplying signals to the autopilot. Pressing the navigation transfer switch on the automatic pilot controller transfers signals from captain's to first officer's navigation instruments.

AUTOPILOT - DESCRIPTION AND OPERATION

1. Description

A. The autopilot is that portion of the auto flight control system which operates the flight control surfaces of the airplane as needed to maintain straight and level flight or to maneuver in response to pilot commands. Operating modes can be selected to provide automatic control of:

(1) Yaw damping

(2) Constant altitude

(3) Coordinated turn

(4) Vertical speed

(5) Constant indicated airspeed or Mach number

(6) Pitch damping during turbulence

(7) Preselected compass heading

(8) Omnirange flying and localizer guidance

(9) ILS control

(10) Split-axes control

B. Yaw Damper

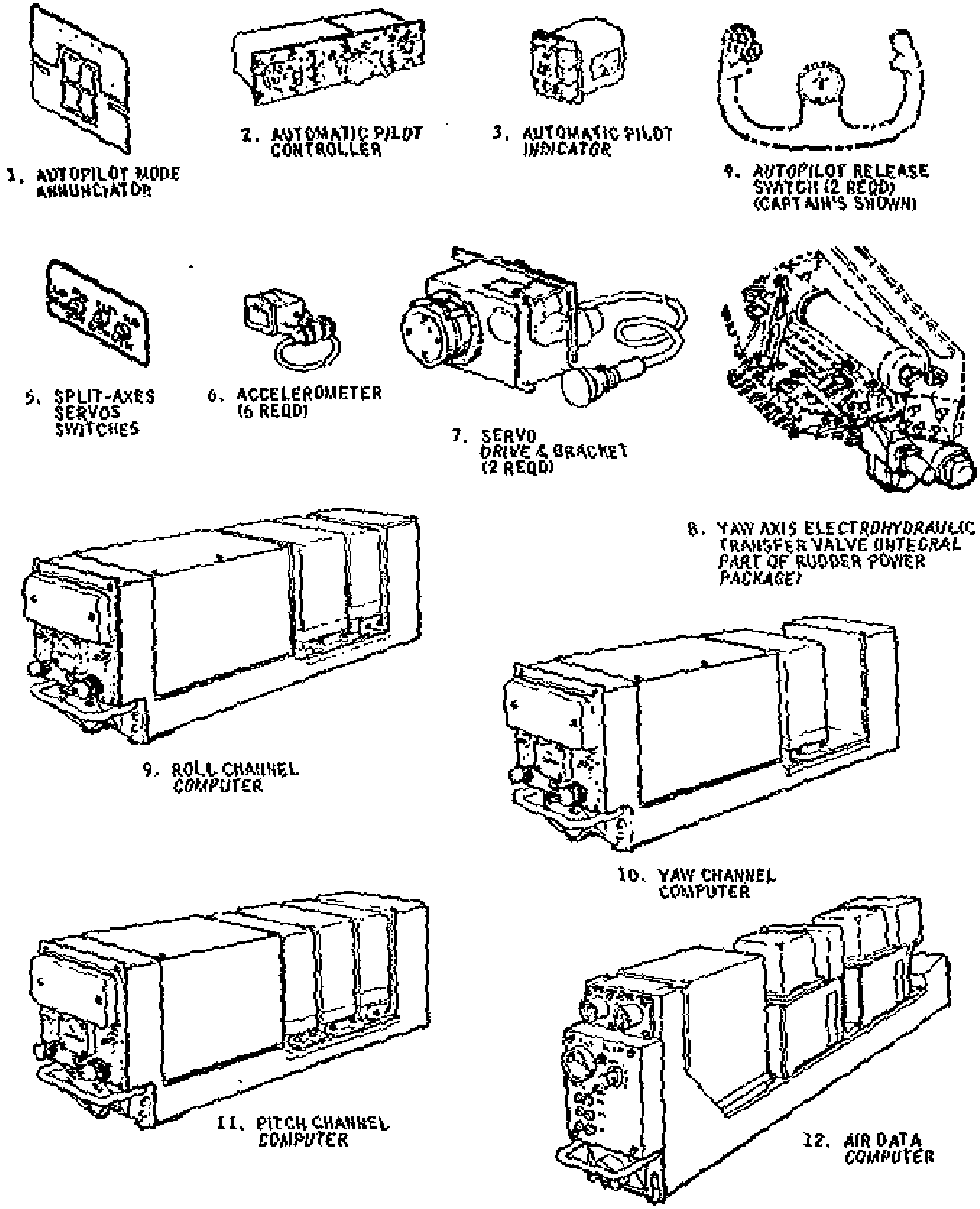
(1) The yaw damper function can be engaged separately to provide necessary yaw damping during manual flying. Yaw damper control is not reflected at the rudder pedals.

C. Autopilot Control

(1) When the complete system is engaged, the autopilot controls the airplane in roll, pitch, and yaw axes. The existing attitude and directional reference is automatically maintained.

D. System Components (See Figure 1.)

Component	Function
(1) Autopilot mode annunciator	Provides visual display of radio guidance/approach mode controlling autopilot.
(2) Automatic pilot controller	Provides fingertip controls to enable the captain and first officer to engage the autopilot, select the various modes of operation, and to initiate maneuvering commands.
(3) Automatic pilot indicator	Provides visual indication of aileron and elevator servo drive trim conditions and output of yaw actuator position transducer. Lights indicate autopilot off, glide path armed, auto trim off.
(4) Autopilot release switches	Provide disengagement of the roll and pitch axes of the autopilot.
(5) Autopilot servos (split-axes) switches	Provide independent cutoff of yaw, roll, and pitch control functions.
(6) Accelerometers (6 req'd.)	Translate acceleration in yaw, roll, and pitch axes into electrical signals for damping short-period attitude changes.
(7) Servo drives and brackets (2 req'd.)	Initiate movement of the ailerons and elevator in response to amplified signals from the roll and pitch channels.
(8) Yaw axis electrohydraulic transfer valve (part of rudder hydraulic power package)	Provides the means for yaw channel input to the main control valve in the rudder hydraulic power package.
(9) Roll channel computer	Provides roll axis interlock; computes and shapes error and command signals to drive the aileron servo drive.
(10) Yaw channel computer	Provides automatic stability augmentation and turn coordination in response to command signals from the autopilot sensing and control devices.



Autopilot System Components
Figure 1

Component	Function
(11) Pitch channel computer	Provides pitch axis interlock; computes and shapes error and command signals to drive the elevator servo drive.
(12) Air data computer	Provides signals for autopilot vertical speed, altitude hold, Mach Q/p data airspeed (Q) switching of autopilot command parameters, and airspeed and Mach number data.

2. Operation

A. Yaw Axis

(1) Synchronization

(a) With yaw axis circuit breakers closed and power applied, the autopilot provides self-synchronization within the yaw channel computer. The synchronization provides a null output from the torquer amplifier to the rudder electrohydraulic transfer valve. With pitch and roll axes circuit breakers also closed, synchronization to airplane magnetic heading, as sensed by the directional gyro, is provided within the yaw channel computer by a heading synchronizer. The heading reference output signal is routed to the roll channel computer.

(2) Yaw Damper

(a) The yaw damper mode is engaged when yaw axis ac and dc circuit breakers are closed and the servos engage lever on the automatic pilot controller is moved to yaw damper. The servos engage lever is held at yaw damper if all yaw axis engage path interlock requirements are met. The yaw channel computer provides rudder command signals to dampen the airplane dutch roll characteristics during manually and automatically controlled flight. Because of the rudder hydraulic and linkage tie-ins with the manual controls, automatic yaw damper control actions are not reflected at the rudder pedals. Further, the pilot can maneuver the airplane in a normal manner through the rudder pedals with no opposing force or action from the yaw damper.

(b) With pitch and roll axes circuit breakers closed, the yaw channel computer also provides rudder command signals to assist turn maneuvers.

(3) Autopilot

(a) The autopilot mode is engaged when yaw axis, pitch and roll axes, and air data circuit breakers are closed and the servos engage lever is set at autopilot. This continues yaw damper operation and also engages the roll and pitch axes. The yaw, roll, and pitch axes are series interlocked for autopilot control. When an interlock interruption occurs in any axis, the autopilot mode is automatically disengaged. If the pitch or roll axis is malfunctioning, the servos engage lever drops to yaw damper position and the autopilot off light comes on as an indication to the pilot. The light remains on until one of the autopilot release buttons is pressed.

(b) During the approach phase of ILS operation, the yaw channel computer receives a roll command to rudder signal that compensates for long-term airplane heading asymmetries such as loss of an engine. In addition, a heading synchronizer in the yaw computer module receives heading signals from the directional gyro and provides heading reference and heading error data to the roll channel computer for heading hold functions.

B. Roll Axis

(1) Synchronization

(a) With pitch and roll circuit breakers closed and power applied, the autopilot provides continuous synchronization to airplane roll attitude and magnetic heading. This synchronization provides a null output from the aileron servo amplifier to the aileron servo drive motor.

(2) Roll Axis Engage

(a) The roll axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot if all engage path interlock requirements are met.

(b) If the roll axis is engaged when the aircraft is at a roll angle (up to 35 degrees), the airplane automatically returns smoothly to a wings-level condition. When the airplane roll angle reduces to less than 6 degrees, the autopilot automatically couples the airplane to the compass heading (compass system).

(c) Heading hold is initiated with the navigation selector switch on the automatic pilot controller at turn knob and the turn knob at detent, heading hold is automatically established when airplane bank angle is less than 6 degrees.

(d) Automatic disengagement of the autopilot mode occurs when the roll axis monitor detects a malfunction within the roll axis. The servos engage lever drops to yaw damper and the autopilot off light comes on as an indication to the pilot. The pitch and yaw axes may be operated by using the split-axes servo switches (see paragraph D).

(3) Turn Knob

(a) The turn knob, located on the automatic pilot controller, is the primary roll control mode. The knob provides a manual turn control function for changing airplane heading. The turn knob must be in detent to engage the autopilot.

(b) The turn knob operates through the roll axis (aileron channel) to establish and hold the desired bank angle required to initiate a heading change. The degree and direction of bank angle is proportional to the amount and direction of turn knob rotation. When the turn knob is moved from detent, the roll axis automatically decouples from the heading reference. As long as the turn knob is left out of detent, the airplane remains in a turn at the commanded bank angle. When the turn knob is returned to detent, the airplane returns to wings level and is recoupled to the heading reference which exists when bank angle becomes than 6 degrees. Operation of the turn knob takes priority over any lateral control mode.

(4) Heading Select

(a) The heading select mode operates through the roll axis to establish and follow a chosen heading set on the course indicator or equivalent heading display. The heading select cursor on the indicator is positioned at the desired heading by using the heading select sync knob. With the navigation selector switch set at heading select, the airplane is automatically banked at a controlled roll rate up to a limited bank angle, to execute a turn toward the selected heading. As this heading is approached, the airplane is smoothly brought to wings-level. The airplane is aligned with the selected heading and is directed to maintain that heading until new commands are given to the autopilot.

(5) Localizer/Omnirange

(a) The roll channel computer provides aileron control in response to lateral radio signals (VOR and ILS) if the navigation selector switch is rotated to LOC/VOR and the navigation receiver is turned to the proper frequency. Desired omniradial heading or inbound runway heading must be set on the pictorial deviation indicator.

(b) Automatic beam capture is initiated by the pilot establishing an appropriate intercept heading using either the turn knob or heading select move. After the airplane rolls out on the intercept course, rotating the navigation selector switch to LOC/VOR establishes heading hold until lateral beam intercept.

(c) At beam intercept, the airplane turns toward the transmitting station at a limited bank angle that is a function of beam error, rate of change of beam error (ILS only), and course (runway) heading error. When the airplane attains the selected radial at beam center (on-course) the autopilot automatically integrates for crosswind correction. As the airplane approaches the zone-of-confusion above the VOR transmitter, interlocks decouple the beam signal, and the airplane is directed to fly at the drift-corrected radial heading. After passing the VOR station, the beam is again switched into roll command circuitry and the autopilot tracks the outbound radial.

(6) ILS

(a) With the navigation selector switch set to ILS at a specified beam error, glide path control is initiated. The pitch channel computer controls descent to glide path beam center channel while the roll computer maintains the airplane on beam center to minimum altitude or disengagement.

(b) Interlocks prevent selection of ILS unless the pitch axis is engaged and appropriate radio receiver is tuned to ILS frequency. The navigation selector switch will not hold in ILS and glide path capture is prevented.

(7) Auxiliary Navigation Control (Optional)

The autopilot roll axis can provide automatic control in response to track error and cross-track deviation information received from an auxiliary navigation or inertial guidance system to maintain a selected ground track or sequence of ground tracks. Auxiliary navigation or inertial navigation is engaged by pressing and rotating the navigation selector switch to AUX NAV after setting the initial conditions in the auxiliary navigation or inertial controller. Upon engagement, the airplane is automatically turned to intercept auxiliary navigation track.

C. Pitch Axis

(1) Synchronization

(a) With pitch and roll circuit breakers closed and power applied, the autopilot provides continuous synchronization to airplane pitch attitude, vertical speed, and altitude. This synchronization provides a null output from the elevator servo amplifier to the elevator servo drive motor prior to engagement.

(2) Pitch Axis Engage

(a) The pitch axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot if all engage path interlock requirements are met.

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(b) When engaged, the pitch axis provides a vertical speed hold function. This is the primary pitch control mode. This mode adjusts the pitch attitude of the airplane to maintain the vertical speed existing when the pitch axis was engaged. The vertical speed hold function continues until changed by use of the vertical speed wheel on the automatic pilot controller.

(c) Automatic disengagement of autopilot control occurs when the pitch axis monitor detects a malfunction within the pitch axis. The servos engage lever drops to yaw damper and the autopilot off light comes on as an indication to the pilot. The yaw and roll axes may be operated by using the split-axes servo switches (see paragraph D).

(3) Vertical Speed Control

(a) The detent (center) position of the vertical speed wheel is altitude hold (zero vertical speed). During synchronization, the motor-driven vertical speed wheel follows up to the vertical speed of the airplane, providing a vertical speed reference for the vertical speed hold function at engagement.

(b) When the vertical speed wheel is moved out of detent, the airplane assumes, and adjusts as required, a pitch attitude to hold the commanded vertical speed. The pilot observes the rate of climb or descent on the vertical speed indicator and manually adjusts the vertical speed wheel to obtain the desired vertical speed. The pitch selector switch returns to vertical speed when the vertical speed wheel is manually moved. The navigation selector switch returns to turn knob when the airplane is under glide path control mode if the vertical speed knob is manually moved. If the system is in the glide path extension mode, and was manually or automatically engaged to this mode, manual movement of the vertical speed wheel reverts the system to the turn knob and/or vertical speed modes.

(4) Altitude Hold

(a) Altitude hold is established when the vertical speed wheel is at altitude hold (zero vertical speed). The airplane altitude existing when the vertical speed wheel is returned to the detent (altitude hold) position is maintained until a change in vertical speed is commanded.

(5) Pitch Damp

(a) When the pitch selector switch is pressed and rotated to the pitch damp position, the pitch damp mode is initiated. During this mode, which is used for turbulence penetration, automatic pitch trim is disconnected. Pitch trim is accomplished by manual actuation of the horizontal stabilizer controls. A "soft" pitch attitude damping function is provided by the autopilot to minimize pitch deviations. There is no vertical gyro pitch attitude reference during operation of pitch damp mode.

(6) Glide Path Control - Automatic

(a) The autopilot pitch axis provides automatic glide path control from signals received from a glide path receiver. The system automatically captures the glide path beam when the pitch axis is engaged, the glide path receiver is tuned to an ILS frequency, and the navigation selector switch is at ILS. At glide path capture the pitch selector switch returns to vertical speed if the switch was at another position.

(b) A 10-second capture period begins at glide path capture. During this period, a fixed vertical speed command is applied to the pitch channel computer, causing the airplane to descend at approximately 700 feet per minute. The vertical speed wheel follows up to this commanded rate of descent.

(c) After the 10-second capture period terminates, the airplane is in the glide path control phase. In this phase, the airplane follows the glide path beam.

(d) The vertical speed wheel follows up to the rate of descent during the control phase. Heading, localizer, and glide path gain programming are initiated as a function of radio altimeter altitude (analog dc output). If the radio altimeter malfunctions, localizer and glide path gains are programmed at glide path capture to compensate for ILS beam convergence. The control phase ends where the pilot terminates the automatic approach to land the airplane manually.

(7) Glide Path Extension - Manual

The glide path extension mode is manually engaged by placing the pitch selector switch at G/P EXT. This mode can be used by the pilot to initiate glide path second-stage gain programming only when glide path is energized (capture +10 seconds), the radio altimeter has failed or is not connected to the autopilot, and the middle marker beacon is not passed. If the radio altimeter is disabled or not installed, glide path gains are second-stage programmed automatically upon interception of the middle marker beacon.

(8) IAS Hold

(a) The IAS (indicated airspeed) hold mode is engaged by moving the pitch selector switch to the IAS hold position. The indicated airspeed existing at the time of engagement is maintained by automatic adjustment of the airplane pitch attitude.

(b) With the pitch axis engaged, the vertical speed hold function automatically controls vertical speed. When the desired indicated airspeed is attained, the pitch selector switch is rotated to the IAS hold position. Automatic elevator control adjusts pitch attitude to maintain the desired airspeed; throttle adjustment will maintain rate of climb or descent.

(c) When the desired altitude is reached, moving the vertical speed wheel to the detent disengages IAS hold. The pitch selector switch returns to the vertical speed position and altitude hold is engaged.

(9) Mach Hold

(a) The Mach hold mode is engaged by moving the pitch selector switch to the Mach hold position. The Mach number existing at the time of engagement is maintained by automatic adjustment of the airplane pitch attitude. As the airplane climbs at a constant speed, the Mach number increases with altitude. When the desired Mach number is attained, the pitch selector switch is pressed and rotated to the Mach hold position. The airplane then climbs at a decreasing airspeed to maintain the desired Mach number. Moving the vertical speed wheel to the detent disengages the Mach hold mode. The pitch selector switch returns to the vertical speed position and the altitude hold mode is engaged.

D. Split-Axes Operation

(1) The three autopilot (split-axes) servo switches, located on the flight instrument panel provide independent cutoff of roll, pitch, and yaw control functions of the autopilot. In this manner, the pilot may use manual control in one or two axes while the autopilot retains control in the remaining engaged axes. In addition, even though a malfunction occurs in one or more control channels a portion of the autopilot may still be used. Split-axes operation also provides approach operation with manual pitch axis control.

(2) The roll and pitch channels can be split off individually, but the yaw channel can not. If the yaw channel is to be split off, both rudder and aileron servo switches must be placed in their off positions. This is necessary due to roll channel dependence on yaw damper for proper performance.

AUTOPILOT - DESCRIPTION AND OPERATION

1. Description

A. The autopilot is the portion of the auto flight control system which operates the airplane flight control surfaces to maintain straight and level flight or to maneuver the airplane in response to pilot commands. Modes of operation are selected on the automatic pilot controller and are as follows:

(1) Yaw damper

(2) Attitude control

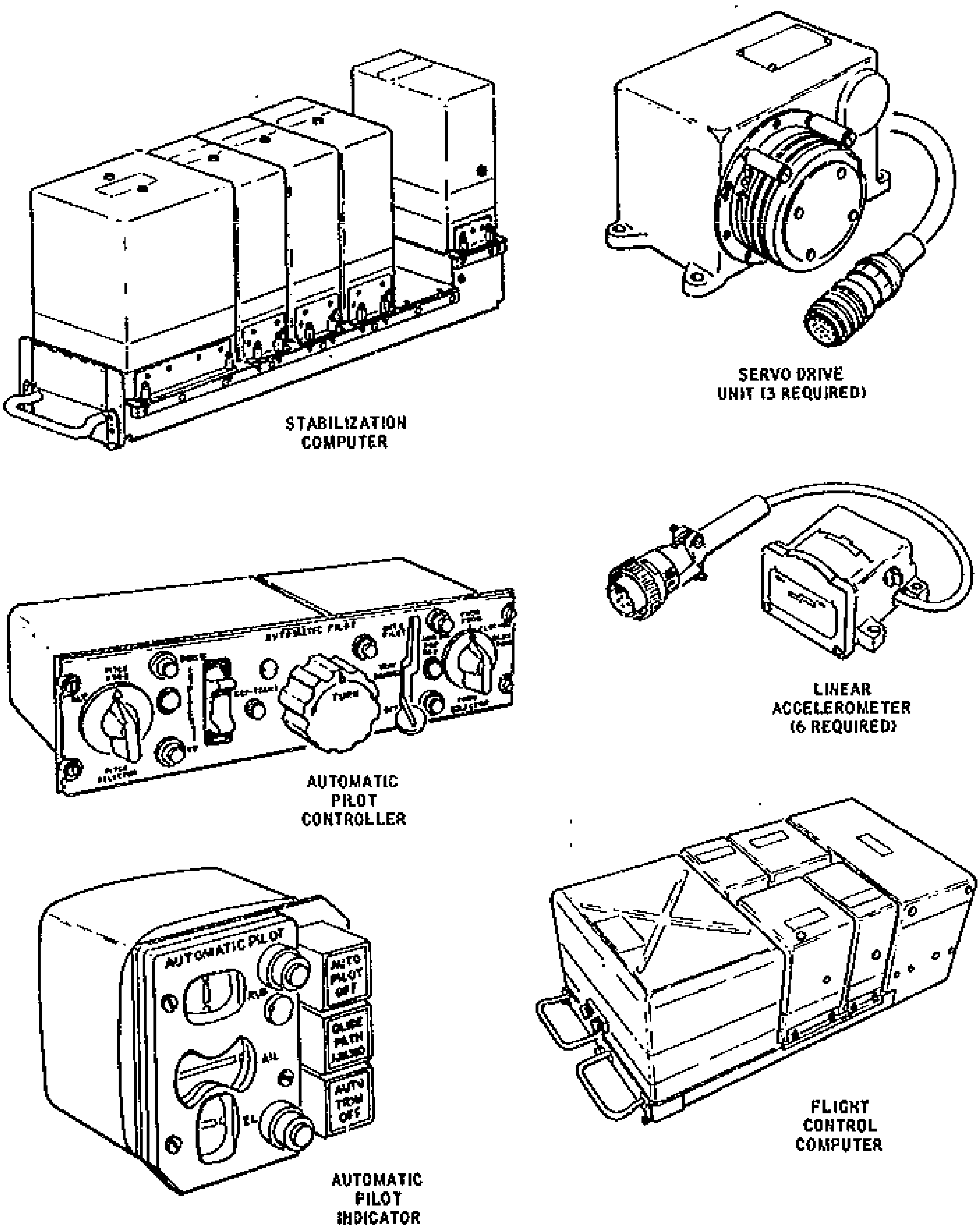
(3) Altitude control

(4) Navigational guidance

(5) Heading selection.

B. The autopilot system consists of the following components; (see Figure 1).

Components	Function
(1) Automatic pilot controller	Provides fingertip controls to enable captain or first officer to engage autopilot, select various modes of operation, and to initiate maneuvering commands.
(2) Flight control computer	Provides necessary shaping and amplification of stabilization and command signals received from autopilot sensing elements.
(3) Stabilization computer	Power amplifies command signals received from flight control computer to drive rudder, elevator, and aileron servo drive motors. Also provides signals for horizontal stabilizer trim (longitudinal trim) motor actuation.
(4) Gain calibrator	Adapts the gains of the autopilot system amplifiers to the specific requirements of the airplane.



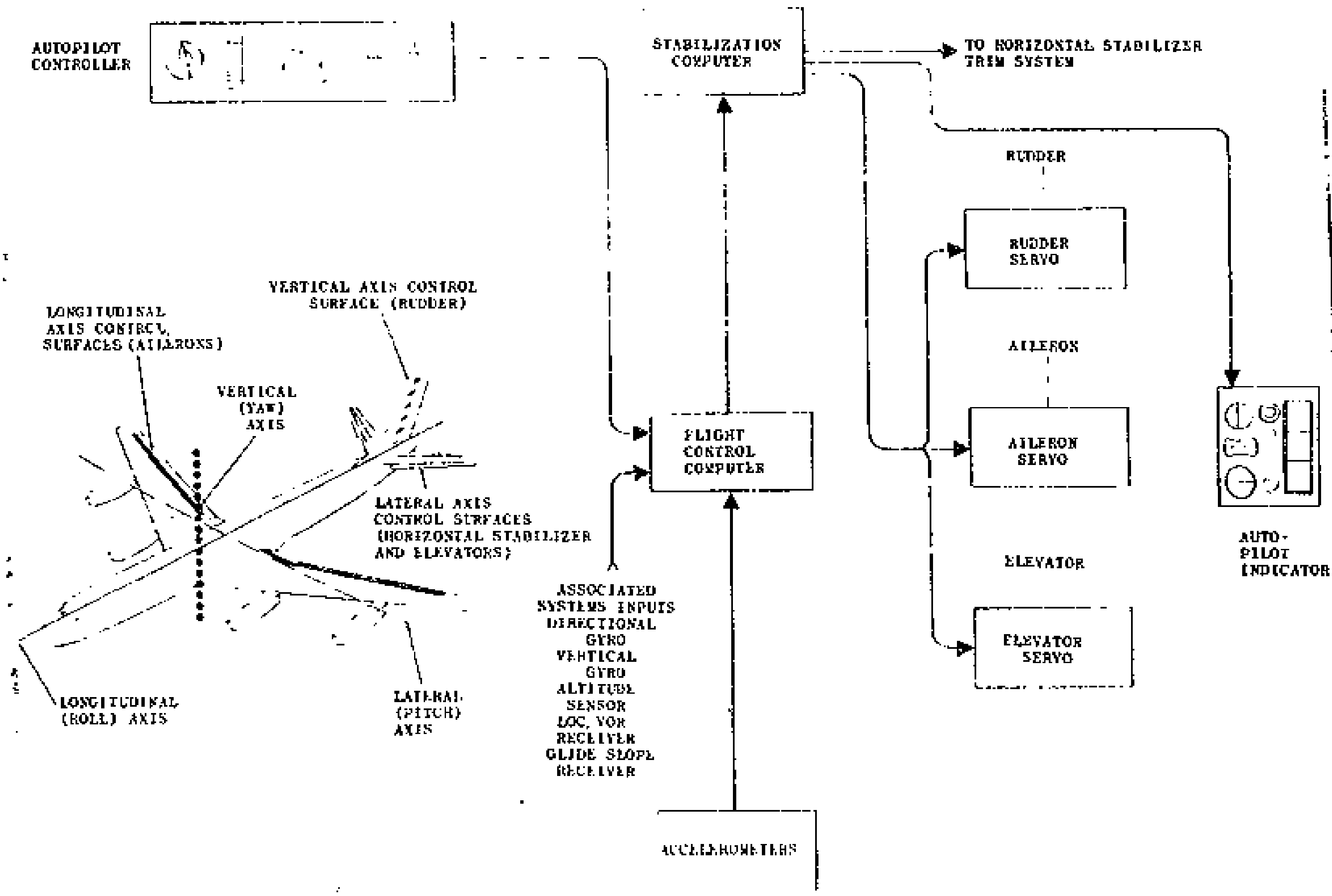
Autopilot System -- Components
Figure 1

Componente	Function
(5) Linear accelerometers	Converts acceleration as sensed in roll, pitch, and yaw axes to electrical signals which are then applied to the computers for use as command signals for damping attitude changes.
(6) Servo drives and brackets (three used in system)	Initiate movement of ailerons, elevator, and rudder in response to roll, pitch, and yaw axes command signals.
(7) Automatic pilot indicator	Provides visual indication of elevator, rudder, and aileron servo drive conditions. Lights indicate auto trim off, glide path armed, and autopilot off.

C. Signals are required from the following sources, but the associated components are not considered part of the autopilot sy tem: pitch and roll reference (vertical gyro), heading (directional gyro), localizer and omnirange receiver, glide slope receiver, doppler computer, and the first officer's or the alternate pitot and autopilot static air systems.

2. Operation

A. When the autopilot is engaged, the system controls the airplane in the roll, pitch, and yaw axes. The existing attitude and directional reference is maintained automatically. The yaw damper function can be engaged separately to provide necessary yaw damping during manual control. The basic reference position to which the autopilot controls the airplane is established by the vertical and directional gyros. If the airplane deviates from the referenced path, signals from the gyros are applied through control amplifiers to drive the appropriate control surface servo drive unit to correct the deviation. The amount of surface correction is proportional to the amount of deviation error. Accelerometers acting in pairs supply signals proportional to angular velocity rates of change to dampen or to make the correction smooth. Two of the accelerometers are also used singularly to provide vertical and lateral damping. Signals from other sources, such as the autopilot controller and radio receivers, are summed with the reference path signals in the appropriate flight control computer module to provide command maneuvers or radio guidance. Each of the flight control computer modules (roll, pitch, and yaw command computers) drives the corresponding servo amplifier in the stabilization computer. The servo amplifiers drive their respective servo drive unit motors to initiate control surface movement. Figure 2 shows the basic autopilot system in block diagram form.



Autopilot System -- Basic Diagram
Figure 2

3. Longitudinal Path (Pitch) Control

A. Longitudinal path control (see Figure 3) includes all the means by which the autopilot system can hold or change the airplane pitch attitude during altitude control, glide path descent, pitch rate command, coordinated turns, or straight and level flight.

B. Pitch Angular Acceleration Signal

(1) The forward and aft pitch accelerometers each produce a signal proportional to linear acceleration in a vertical plane along the airplane longitudinal axis. The two signals are summed to produce a signal which is proportional to airplane pitch angular acceleration. This signal is amplified, demodulated, and applied to two networks: a filter network which frees the signal of noise, and a lag network which develops rate from the acceleration signal. The signal from each network is attenuated in the gain calibrator, then summed and modulated to produce an ac signal which is fed to the elevator servo amplifier.

C. Vertical Gyro Pitch Signal

(1) The vertical gyro pitch synchro produces a signal which is proportional to airplane displacement about the lateral (pitch) axis. The pitch synchro is connected back-to-back with the pitch followup synchro in the pitch command computer. The output signal from the followup synchro is summed with other signals, attenuated, and further summed with the pitch angular acceleration signal. The combined signal is then applied to the elevator servo amplifier.

D. Pitch Knob (Pitch Rate Controller) Signal

(1) A pitch rate signal is produced when the pitch knob on the controller is moved out of detent. This signal changes the airplane pitch attitude at a rate proportional to the amount of pitch knob displacement. The signal is attenuated as a function of Mach number and passes through contacts of the pitch knob detent relay (1), and the autopilot engage relay (2). Relay (1) is energized when the pitch knob is out of detent and relay (2) is energized when the servo's engage lever is in the autopilot position. The signal is then summed with other signals and applied to the pitch command computer where it is amplified and used to drive the pitch followup motor. The motor rotates the followup synchro to a new position through the reduction gear train. Tachometer feedback is applied to the pitch followup input as a motor damping signal and is also fed through the contacts of the vertical path relay (3) an isolation transformer, and an attenuator to be summed with the pitch angular acceleration signal. This latter path acts as a pitch boost signal to speed airplane entry into commanded pitch maneuvers.

(2) When the pitch knob is returned to detent, the followup motor is electrically disconnected from its servo amplifier. The motor control field

is then shorted (clamped) to prevent the synchro from changing position. The synchro output must be null to establish an airplane steady-state attitude. Once the synchro is clamped, the airplane must seek and hold an attitude so that the vertical gyro pitch signal to the followup synchro will produce a null output. Any deviation of the airplane from this attitude will create an output signal from the followup synchro to the elevator servo amplifier. This initiates elevator movement and a corresponding change in airplane attitude until a null is re-established.

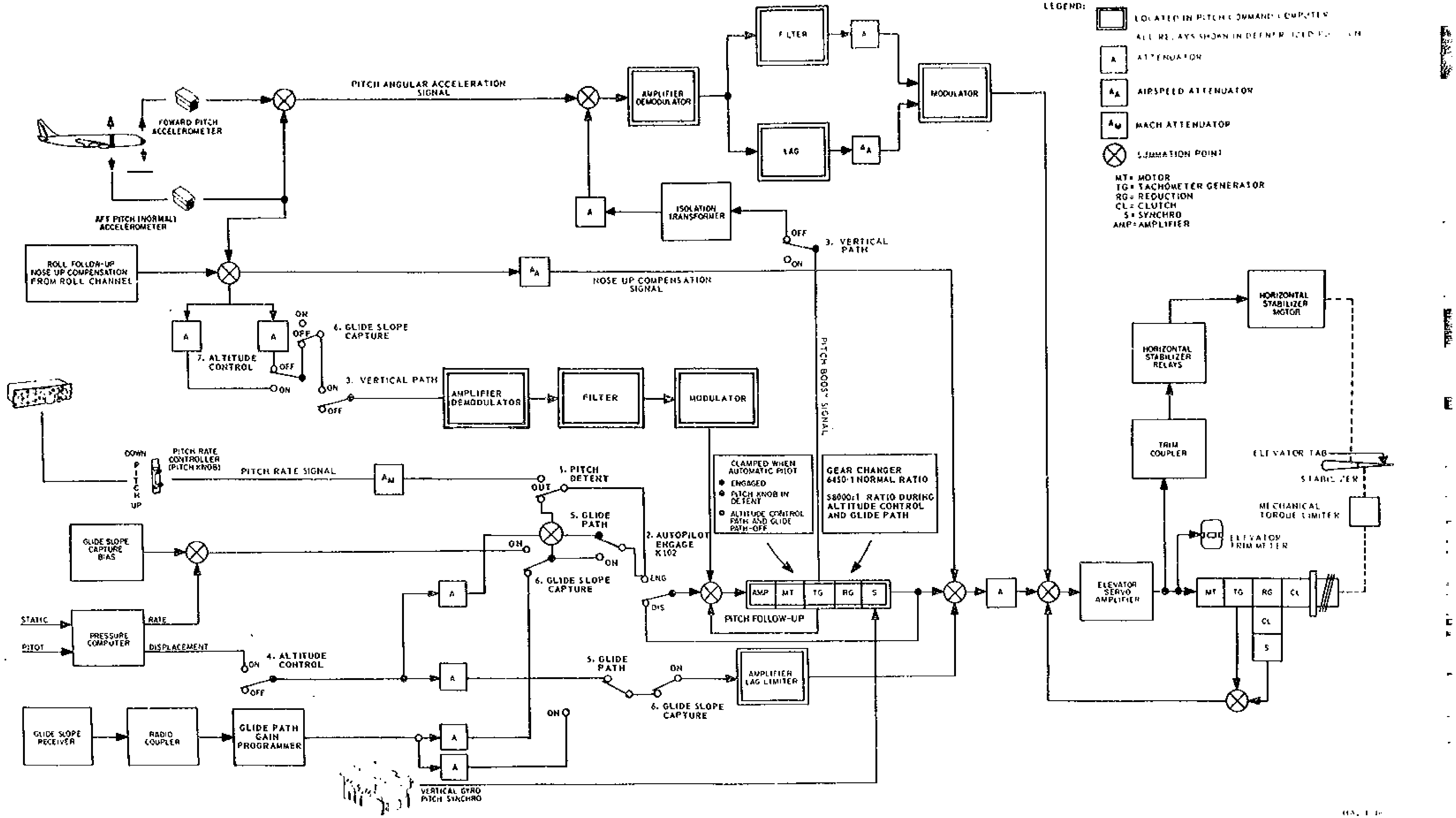
E. Altitude Control Signals

(1) The altitude control signal, generated in the pressure computer from barometric pressure, is routed through contacts of the altitude control relay (4). This relay is energized when the pitch selector switch on the controller is moved to the altitude (ALT) position. The signal is applied to two paths. One path carries that portion of the signal which corrects for short period deviations from altitude due to gusts and other disturbances. This signal is attenuated and passed through contacts of glide path relay (5) and glide slope capture relay (6) to an amplifier lag-limiter which amplifies and limits the magnitude of the signal. The amplifier lag-limiter output is summed with other signals, attenuated, and routed directly to the servo amplifier. The purpose of lagging this signal is to filter out any spurious signals caused by sudden changes in angle of attack.

(2) The other altitude control signal path carries that portion of the signal which corrects for long period deviations from altitude (gradual changes in airplane weight and center of gravity resulting from fuel consumption). This signal is attenuated, summed with other signals, and then routed through the contacts of the glide path relay (5) to the autopilot engage relay (2). The signal follows the same path as the pitch rate signal from this relay, and pitch followup action is the same.

F. Aft Pitch Accelerometer Signal

(1) The aft pitch accelerometer also produces an additional damping signal which is used during altitude or glide path control. This signal is summed with the roll followup resolver signal, attenuated, and routed through the contacts of altitude control relay (7). This relay selects one attenuator for altitude control or another attenuator for glide path control. The signal is applied through the contacts of the glide slope capture relay (6), vertical path relay (3), an amplifier demodulator, filter, and modulator to the pitch followup. Relay (3) is energized only during altitude or glide path control. Relay (6) is energized for 10 seconds after glide slope capture and prevents the aft accelerometer damping signal from reaching the pitch followup.



Longitudinal Path (Pitch) Control -- Flow Diagram
Figure

G. Roll Followup Resolver Signals

(1) When the airplane banks, increased normal acceleration caused by the turn results in the aft accelerometer producing an undesirable signal. The roll followup resolver (located in the roll command computer) provides a signal which is used to cancel out the undesirable signal. The roll followup resolver also provides a nose up compensation signal which is fed through an airspeed attenuator to the elevator servo amplifier.

H. Glide Path Signals

(1) The glide path capture circuits are armed when the turn selector switch on the controller is moved to glide path position, the navigation receiver is tuned to an ILS frequency, and a fly-up or fly-down radio signal is present. The glide path armed light on the autopilot indicator comes on until the airplane reaches the 30 mv region of the glide slope beam. At this point, the glide path armed light goes off and the glide slope capture relay (6) is energized for approximately 10 seconds. The relay contacts open glide path signal circuits and short the normal acceleration signal. Glide slope capture bias and altitude rate signals are routed through contacts of the glide slope capture relay (6), glide path relay (5), and autopilot engage relay (2) to the pitch followup. The glide slope capture bias is of such magnitude and phase that an altitude rate signal created by the airplane descending 700 feet per minute will cancel it (700 feet per minute is the average glide slope beam rate of descent). During the 10 seconds that the glide slope capture relay is energized, the airplane attitude is changed from its initial path to a path of descent approximating the glide slope beam, independent of normal acceleration or glide slope radio signals. When the glide slope capture relay is deenergized after 10 seconds, the altitude rate and capture bias signals are removed, the short is removed from the normal acceleration signal, and the glide slope radio signals are allowed to enter the system through contacts of the glide path relay (5). Relay (5) is energized from the time that the glide path armed light goes off at glide path capture. The radio signals are then fed through two attenuators and follow the same path as the altitude control signals. During glide path control, altitude control relay (7) is deenergized, automatically discontinuing altitude control. As soon as the glide path armed light goes off, the glide path gain programmer begins to decrease its gain ratio from 3 1/3 to 1 over a period of 100 seconds (if the radio altimeter is inoperative). Thus as the airplane flys down the glide path, the glide path radio signal is smoothly decreased, automatically compensating for the increasing gain of the glide path beam. When the airplane passes over the middle marker, the gain programmer further decreases the gain ratio.

(2) If the radio altimeter system is operative, the glide path programmer begins to decrease the ratio from 3 1/3 to 1 at 1000 feet altitude and from 3 to 1 at 300 feet altitude as the result of radio altimeter analog trip voltage.

I. Elevator Servo System Operation

(1) All longitudinal path signals are amplified in the elevator servo amplifier in the flight control computer. Amplified output is applied to the elevator servo drive, the trim coupler, and elevator trim meter on the autopilot indicator. The signal to the trim coupler actuates either of two relays (up or down) in the airplane horizontal stabilizer trim system to maintain automatic pitch trim.

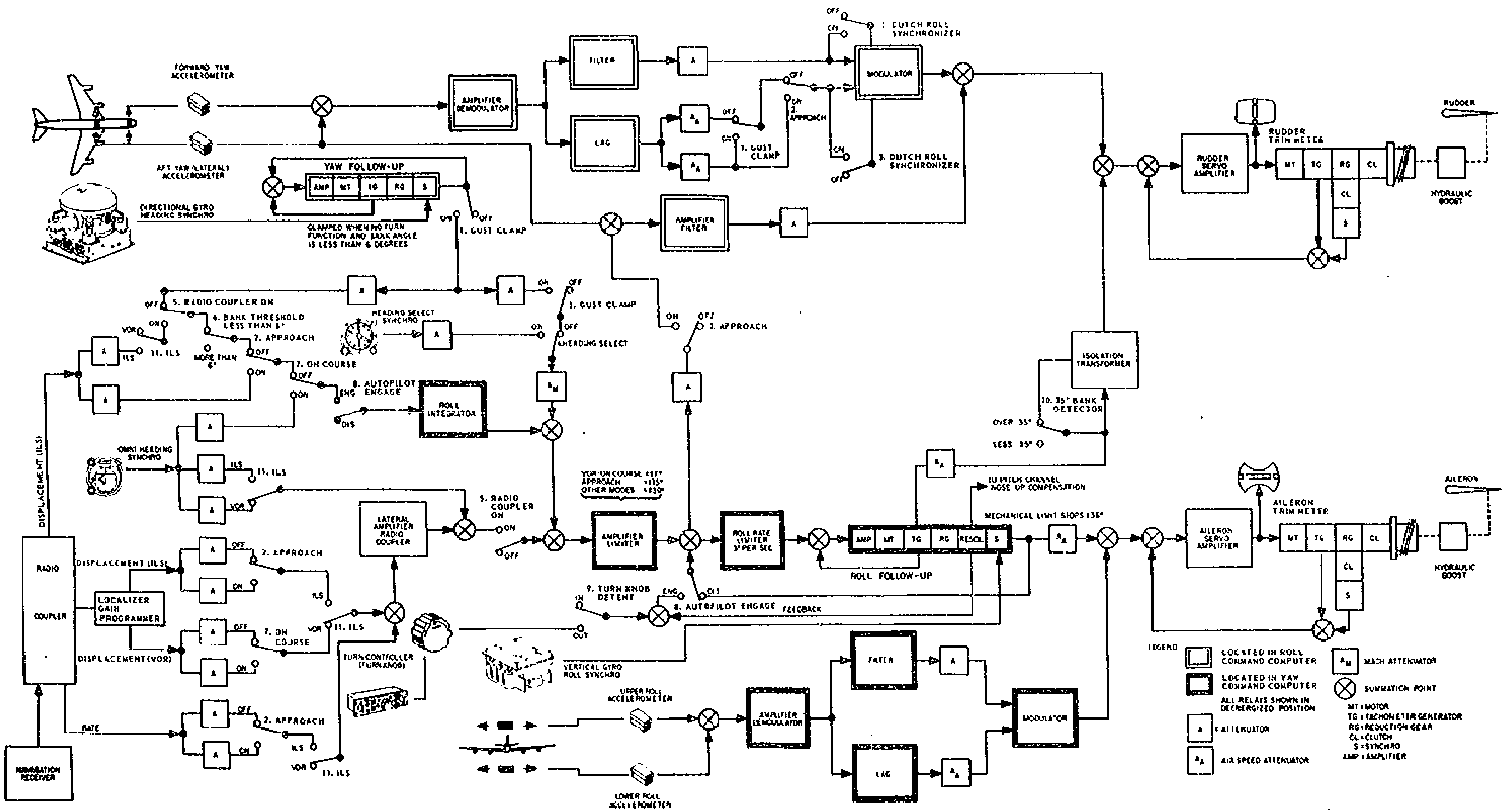
(2) The signal to the elevator servo drive unit drives the servo motor. Torque developed by the motor is amplified through a power gear train and transmitted through a clutch to drive the servo cable drum and move the elevator control system cables. A damping signal is fed back to the servo amplifier by the servo tachometer-generator. When the autopilot is disengaged, a nulling followup signal from a clutched synchro is fed to the servo amplifier to balance the servo system. This clutch is released and the position synchro is locked when the autopilot is engaged. The torque developed by the elevator servo drive unit is transmitted to the airplane control system through a mechanical torque limiter. This limits cable force as a function of flap position, allowing more applied servo force when the flaps are down. Nose down servo force is always limited to lower values than nose-up force.

4. Lateral Path (Roll and Yaw) Control

A. Lateral path control (see Figure 4) includes all the means by which the autopilot system can hold or change the airplane directional attitude during straight and level flight, roll rate commands, coordinated turns, heading select, LOC/VOR bracketing, and approach operation.

B. Yaw Angular Acceleration Signals

(1) The forward and aft yaw accelerometers each produce a signal proportional to linear acceleration in a plane perpendicular to the airplane's vertical axis. The two signals are summed to produce a signal which is proportional to airplane yaw angular acceleration. This signal is amplified, demodulated, and applied to two networks: a filter network which frees the acceleration signal of noise and a lag network which develops rate from the acceleration signal. The lag network portion of the signal is controlled by gust clamp relay (1) and approach relay (2) to provide less attenuation when the autopilot is either locked on a heading reference or is in the approach mode. Rate gain is attenuated as a function of dynamic pressure so that at different airspeeds, the signal gain can vary as required for proper performance. The combined signals are modulated to produce an ac signal which is summed with other signals and routed to the rudder servo amplifier. Dutch roll synchronization relay (3) keeps yaw angular acceleration signals shorted until yaw damper or autopilot modes are engaged. This allows either mode to be selected during a coordinated dutch roll. Rudder coordination is



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Lateral Path Control -- Flow Diagram
Figure 4

initiated by a signal from the aft yaw accelerometer. The output of the accelerometer is developed by lateral acceleration of the airplane. This signal, independent of the forward yaw accelerometer signal, is applied to an amplifier filter, attenuated, and fed directly to the rudder servo amplifier. This continuously positions the rudder to eliminate lateral acceleration.

C. Directional Gyro Heading Synchro Signals

(1) The directional gyro heading synchro is connected back-to-back with the yaw followup synchro. When the airplane is in less than a 6-degree bank with no turn functions inserted in the autopilot, the gust clamp relay (1) is energized. The yaw followup motor is then clamped, permitting the followup synchro signal to enter the rudder and aileron servo amplifiers. To get to the servo amplifiers, the signal follows two paths.

(2) The first path carries that portion of the signal that provides corrective roll commands in response to heading displacement errors (heading-into-roll signal). This signal is routed through contacts of the gust clamp relay (1), an attenuator, a second set of gust clamp relay contacts, and contacts of the heading select relay (4). The signal is then attenuated as a function of Mach number and passes through two summation points, an amplifier-limiter, and a roll-rate limiter. The amplifier-limiter limits signals so that they will never command more than 30 degrees of roll attitude. The roll rate limiter limits all signals (except VOR signals, which are limited to 1 degree per second) so that the commanded roll rate will not exceed 4 degrees per second. Output of the roll rate limiter is applied to the roll followup where it is further amplified to drive the followup motor. The motor rotates the followup synchro to a new position through reduction gearing to produce a command signal which is applied to the aileron servo amplifier.

(3) The second path carries the portion of the followup synchro signal that eliminates any steady-state heading errors during normal level flight. This signal is routed through contacts of the gust clamp relay (1), an attenuator, and contacts of the radio coupler-on relay (5), bank threshold relay (6), approach relay (2), on-course relay (7), and autopilot engage relay (8). The signal is then applied to a roll integrator and summed with the heading-into-roll signal, after which, the same path previously described for the heading-into-roll signal is followed to the aileron servo amplifier.

(4) When a turn function is inserted into the autopilot system, gust clamp relay (1) is deenergized and yaw followup is unclamped. This prevents the heading signal from entering the aileron and rudder channels. Instead, the yaw followup synchro now drives the unclamped motor through a closed followup loop until the heading signal is nulled out. When the turn function is removed, and the bank angle drops below 6 degrees, the gust clamp relay (1) is energized, the yaw followup motor is clamped and heading information is again applied to the aileron and rudder channels. This clamps the airplane to a particular heading reference and assures that gusts will not cause deviation from that heading.

D. Roll Angular Acceleration Signals

(1) The lower and upper roll accelerometers each produce a signal proportional to linear acceleration in a plane perpendicular to the airplane longitudinal axis. The two signals are summed to produce a signal proportional to airplane roll angular acceleration. This signal is amplified, demodulated, and applied to two networks: a filter network which frees the signal of noise, and a lag network which develops rate from the acceleration signal. The output from each network is attenuated and applied to a modulator. The rate gain signal from the lag network is attenuated as a function of dynamic pressure so that at different airspeeds, the signal will vary. The combined signal is modulated as an ac command signal and routed through two summation points to the aileron servo amplifier.

E. Turn Knob (Turn Controller) Signal

(1) When the turn knob on the autopilot controller is moved out of detent, a turn controller signal is inserted into the autopilot system. With the turn knob out of detent, the turn knob detent relay (9) is energized, permitting the signal to flow through contacts of autopilot engage relay (8) to the roll rate limiter. Output of the limiter is applied to the roll followup where it is used to drive the followup motor. The motor rotates the followup synchro to a new position. This new reference is passed to the aileron servo amplifier which originates aileron commands to drive the aileron servo drive unit. The airplane will bank until the vertical gyro is tipped the same number of degrees as the rotation of the followup synchro. At this point, the vertical gyro and followup synchro signals cancel and remove the command for aileron action. Mechanical limit stops assure that maximum bank angles will not exceed 36 degrees.

(2) The airplane remains coordinated during turns as it did during straight and level flight. One signal from the aft yaw accelerometer enters the rudder channel to eliminate errors in turn coordination. Another signal, proportional to commanded roll rate, is routed from the roll followup tachometer-generator, through an attenuator, and an isolation transformer, to the rudder servo amplifier. This signal provides rudder action during roll maneuvers to assure well coordinated turn entry and exit. Thirty-five degree bank detector relay (10) energizes when the autopilot is engaged and bank angles are less than 35 degrees to allow roll rate signals into the rudder channel. If the autopilot is disengaged, either in yaw damper mode or with over 35 degrees bank angle, the detector relay becomes deenergized and shorts the isolation transformer primary windings to prevent signal flow.

F. Roll Followup Resolver Signal

(1) The roll command resolver, located in the roll followup, puts out a double signal: one for nose-up compensation which is applied to the longitudinal path control channel (see paragraph 3), and one for

feedback to the followup. The resolver is tied mechanically through a gear train to the followup motor and synchro. The feedback signal is routed to the followup to balance the turn controller or other signals entering the followup. In effect, the feedback stops followup action when the synchro has rotated sufficiently to satisfy the command signal to the followup. If the turn knob is rotated for a specific bank, the followup will operate until that specific bank is accomplished. At that time, the feedback signal is equal to and opposite the turn command signal and nulls out the command signal, maintaining the command bank. When the turn knob is returned to the detent, the feedback signal is greater than the turn command signal and the synchro is driven in the opposite direction to command a rollout. When the autopilot is disengaged, any bank error signal from the vertical gyro is nulled through the contacts of autopilot engage relay (8). However, the bank angle signal remains in the resolver, and when the autopilot is engaged, the feedback signal rotates the synchro back to null. If the autopilot is engaged during a coordinated turn, the airplane will roll out to a wings-level attitude.

G. Heading Select Signal

(1) When the turn selector switch is rotated to the heading select position, preselected heading control is established. The heading select relay (4) is energized, permitting a heading select signal from the heading select synghro to enter the autopilot system. The signal is attenuated as a function of Mach number and applied to the amplifier-limiter. The amplifier-limiter contains three bank angle limiting circuits: 30 degrees for heading, heading select, and omnirange or localizer bracketing; 15 degrees for approach; and 7 degrees for VOR on course control. From the amplifier-limiter, the signal is routed through the roll rate limiter to the roll followup, where it drives the followup to a new reference. The followup synchro signal is applied to the aileron servo amplifier and the airplane is banked into a coordinated turn. At the preselected heading, the error signal is reduced to zero, commanding zero bank angle, and the airplane rolls out level.

(2) The heading select signal originates in the captain's or first officer's course indicator when a heading is manually set in the indicator. The heading select signal can be selected from either indicator by using the navigation transfer button on the autopilot controller. Auto-coupling flag indicators on the captain's and first officer's instrument panels indicate which course indicator is in use.

H. VOR Bracket Signals

(1) When the navigation receiver is tuned to a VOR frequency and an omniradial is selected, an error signal from the omniheading synchro enters the autopilot system. The error signal is proportional to the difference between the selected omniheading and the existing airplane heading. When the turn selector switch is rotated to the LOC/VOR

position and the beam signal strength decreases to 100 millivolts, the radio coupler on relay (5) is energized. The omniheading synchro error signal is attenuated and routed through the VOR contacts of the relay (11) to a summation point. A radio beam displacement signal is attenuated and routed through contacts of the on course relay (7), ILS relay (11), and a lateral amplifier to arrive at the summation point simultaneously with the omniheading error signal. The combined signal is passed through contacts of radio coupler on relay (5), the amplifier-limiter, and the roll rate limiter to the roll followup. These signals initiate the turn-on to omnirange radial by driving the followup synchro to a new reference. The airplane is banked into a coordinated turn and bracketing of the beam progresses. The sum of the omniheading error plus the radio displacement determines the commanded bank angle. The amplifier-limiter assures that bank angles will not exceed 30 degrees. When the radio coupler on relay (5) is energized, the localizer gain programmer increases its gain from 0.5 to 1 over a period of 15 seconds. This permits the omniheading error signal to have more authority at the edge of the beam, thus increasing the initial bank angle so that the airplane will turn more quickly toward the VOR/ILS transmitter.

I. VOR On Course Signals

(1) The on course relay (7) operates when radio displacement signals become less than 40 millivolts, when the omniheading error is less than 17 degrees, and the bank angle is less than 6 degrees. This relay selects a different attenuator for the radio displacement signal, changes the bank angle limit from 30 degrees to 7 degrees, arms an over-station sensor circuit in the lateral amplifier, and establishes a circuit to hold itself energized until the turn selector switch is moved from the LOC/VOR position. The relay also connects the omniheading error signal through a second attenuator to the roll integrator to cancel any steady-state radio displacement signals.

(2) Steady-state omniheading signals from the omniheading synchro, routed through contacts of ILS relay (11), are mixed with the integrated omniheading signal which is routed through contacts of the on course relay (7), autopilot engage relay (8), and the roll integrator. This mixing of omniheading signals permits establishment of crab angle headings with the airplane on beam center.

(3) After the on course relay is energized, the over-station sensor is armed. The sensor allows signals to flow through the lateral amplifier until the airplane enters the zone directly above the omnirange station where erratic radio beam signals exist (zone of confusion). When radio signals vary at a rate exceeding 7 millivolts per second, the lateral amplifier is smoothly turned off. When the rate drops below 7 millivolts per second, radio signals remain blocked for approximately 15 seconds. The lateral amplifier is then smoothly turned on and the airplane continues to fly outbound from the omnirange station. During

the period of over-station sensor operation, the autopilot system uses omniheading synchro signals for guidance through the "zone of confusion".

(4) Either the captain's or first officer's navigation receiver and course indicator can supply radio displacement signals for the autopilot LOC/VOR mode of operation. Pressing the navigation transfer button on the autopilot controller transfers the autopilot operation from one navigation system to the other.

J. Doppler Computer Signals

(1) When the turn selector switch is rotated to the doppler position, doppler radar navigation computer signals replace the radio displacement signals from the navigation receiver. When an output is available from computer, an error signal proportional to the difference between the selected and actual airplane track angles, enters the autopilot system. When the cross-track deviation signal strength decreases to 100 millivolts, radio coupler on relay (5) is energized. The heading and deviation signals, through paths identical to those taken by VOR bracket signals, initiate the turn onto the selected track by causing the airplane to bank in a coordinated turn. The sum of track angle error and track deviation determines the commanded bank angles. The required bank is smoothly accomplished at a rate of 3 degrees per second through action of the roll rate limiter. The amplifier limiter assures that bank angles will not exceed 30 degrees.

(2) When the track deviation signals become less than 40 millivolts, the track angle error is less than 17 degrees, and the bank angle is less than 6 degrees, doppler on course mode is initiated. Doppler on course mode is the same as the VOR on course mode: the principal change when doppler on course mode is achieved is the change in bank angle limit from 30 degrees to 7 degrees.

(3) Two features available in the VOR on course mode have no applicability to the doppler on course mode: the over-station sensor and crab angle headings. The over-station sensor never operates in the doppler on course mode since doppler signals do not vary rapidly enough to operate it. The establishment of crab angle headings for doppler operation is achieved by the doppler track angle signal without further integration. The actual track angle error signal is the algebraic sum of drift angle and heading reference, which requires a definite crab angle to bring it to zero.

(4) Transition from one doppler track to another when the doppler navigation computer switches from one stage to another is achieved smoothly through action of the roll rate limiter. Since most doppler stage changes involve heading changes of 15 degrees or less, the autopilot usually remains in the doppler on course mode throughout a doppler commanded flight.

K. Localizer Bracket Signals

(1) When the navigation receivers are tuned to an ILS frequency, ILS relay (11) is energized. This relay selects a different attenuator for the omniheading signal, provides a radio displacement signal path through contacts of the approach relay (2) to the lateral amplifier, allows a second displacement signal to appear at the contacts of the radio coupler on relay (6), and also permits a signal which is proportional to rate of change of radio beam displacement to enter the lateral amplifier. During ILS operation, the omniheading synchro signal which is proportional to rate of change of radio beam displacement to enter the lateral amplifier. During ILS operation, the omniheading synchro signal is used to sense errors between airplane heading and the inbound runway heading as selected by the pilot. When the turn selector switch is rotated to LOC/VOR or glide path positions and beam signal strength falls below 150 millivolts, radio coupler on relay (5) is energized and localizer bracket mode is initiated. All signals at the "on" contacts of radio coupler on relay are then permitted to enter the roll followup through the amplifier and roll rate limiters. At this time, the localizer gain programmer increases its gain from 0.5 to 1 over a period of 15 seconds. This permits the omniheading signal to have more authority at the edge of the beam, thus increasing the initial bank angle so that the airplane will turn more quickly toward the ILS transmitter. As the airplane approaches beam center, the displacement signal assumes greater authority.

(2) As bank angles become less than 6 degrees, a path is created for the second radio displacement signal. This signal is attenuated and routed through contacts of ILS relay (11), radio coupler on relay (5), bank threshold relay (6), approach relay (2), on course relay (7), and autopilot engage relay (8) to the roll integrator. This signal is summed with other signals before entering the amplifier limiter and is used to cancel any steady-state radio displacement signals present during the localizer bracket mode.

L. Localizer Approach Signals

(1) When the turn selector switch is rotated to the glide path position, the autopilot system automatically captures the glide slope beam as it is intercepted (see paragraph 3.H). After completion of localizer bracket and glide slope interception, it is desirable to reduce the bank angle limit and change the signal ratio of radio-rate to displacement. This is accomplished by operation of the approach relay (2). Contacts of this relay change ILS displacement signal attenuators, change rate attenuators, and provide a new path for displacement signals to enter the roll integrator. This new path is not dependent upon the bank threshold relay. When the approach relay is energized, a signal from the amplifier-limiter is attenuated and summed with the aft yaw (lateral) acceleration signal.

(2) Three requirements must be met simultaneously before approach relay (2) is energized: the glide slope must be engaged, radio displacement must be less than 50 millivolts, and cross-beam rate must be less than 2 millivolts per second. During the approach mode, the roll integrator cancels steady-state radio displacement signals so that the airplane may establish the necessary crab angle for crosswind correction and still follow the localizer beam center. The localizer gain programmer starts to decrease its gain ratio from 2 to 1 over a period of 75 seconds. As the airplane flies down the beam, the localizer radio displacement signal is smoothly decreased, thus automatically compensating for the increasing gain of the localizer beam. The approach relay also allows a signal proportional to roll command to enter the lateral acceleration amplifier filter to compensate for long term airplane asymmetries such as those caused by loss of an engine. If the radio altimeter system is operative, both localizer and heading gains are programmed down, beginning at 1000 feet of radio altimeter altitude. Localizer gains are programmed for 75 seconds and heading gains are programmed for 85 seconds.

M. Rudder and Aileron Servo System Operation

(1) Roll control signals are amplified in the aileron servo amplifier. Direct current output from the servo amplifier is electrically limited and applied to the aileron servo drive unit where it is used to drive the servo motor. Torque developed by the motor is amplified through a power gear train and transmitted through a clutch to drive the servo cable drum and move the aileron control system cables. A damping signal is fed back to the servo amplifier by the servo tachometer-generator. When the autopilot is disengaged, a nulling followup signal from a clutched synghro is fed to the servo amplifier to balance the servo system. This clutch is released and the position synchro is locked when the autopilot is engaged.

(2) Yaw control signals are amplified in the rudder servo amplifier. Direct current output from the servo amplifier is electrically limited and applied to the rudder servo drive unit. Operation of the rudder servo drive unit is similar to the aileron servo drive unit operation described in the preceding paragraph.

AUTOPILOT - DESCRIPTION AND OPERATION

1. Description

A. The autopilot is that portion of the auto flight control system which operates the flight control surfaces of the airplane as needed to maintain straight and level flight or to maneuver in response to pilot commands. Operating modes can be selected to provide automatic control of:

(1) Yaw damping

(2) Constant altitude

(3) Coordinated turn

(4) Vertical speed

(5) Pitch damping during turbulence

(6) Preselected compass heading

(7) Omnirange flying and localizer guidance

(8) ILS control

(9) Split-axes control

B. Yaw Damper

(1) The yaw damper function can be engaged separately to provide necessary yaw damping during manual flying. Yaw damper control is not reflected at the rudder pedals.

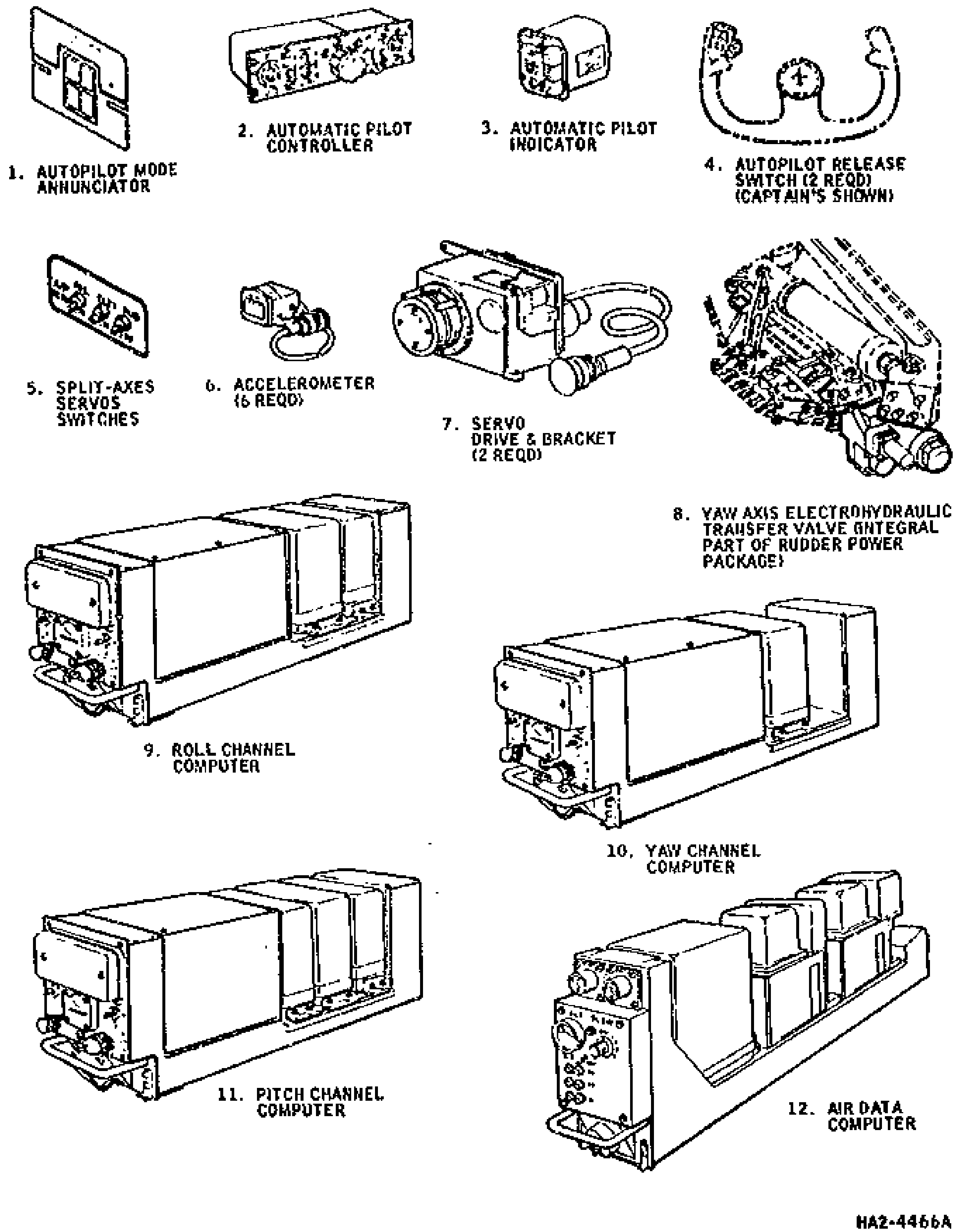
C. Autopilot Control

(1) When the complete system is engaged, the autopilot controls the airplane in roll, pitch, and yaw axes. The existing attitude and directional reference is automatically maintained.

D. System Components (See Figure 1.)

Component	Function
(1) Autopilot mode annunciator	Provides visual display of radio guidance/approach mode controlling autopilot.

Component	Function
(2) Automatic pilot controller	Provides fingertip controls to enable the captain and first officer to engage the autopilot, select the various modes of operation, and to initiate maneuvering commands.
(3) Automatic pilot indicator	Provides visual indication of aileron and elevator servo drive trim conditions and output of yaw actuator position transducer. Lights indicate autopilot off, glide path armed, auto trim off.
(4) Autopilot release switches	Provide disengagement of the roll and pitch axes of the autopilot.
(5) Autopilot servos (split-axes) switches	Provide independent cutoff of yaw, roll, and pitch control functions.
(6) Accelerometers (6 req'd.)	Translate acceleration in yaw, roll, and pitch axes into electrical signals for damping short-period attitude changes.
(7) Servo drives and brackets (2 req'd.)	Initiate movement of the ailerons and elevator in response to amplified signals from the roll and pitch channels.
(8) Yaw axis electrohydraulic transfer valve (part of rudder hydraulic power package)	Provides the means for yaw channel input to the main control valve in the rudder hydraulic power package.
(9) Roll channel computer	Provides roll axis interlock; computes and shapes error and command signals to drive the aileron servo drive.
(10) Yaw channel computer	Provides automatic stability augmentation and turn coordination in response to command signals from the autopilot sensing and control devices.



Autopilot System Components
Figure 1

Component	Function
(11) Pitch channel computer	Provides pitch axis interlock; computes and shapes error and command signals to drive the elevator servo drive.
(12) Air data computer	Provides signals for autopilot vertical speed, altitude hold, Mach Q/p data airspeed (Q) switching of autopilot command parameters, and airspeed and Mach number data.

2. Operation

A. Yaw Axis

(1) Synchronization

(a) With yaw axis circuit breakers closed and power applied, the autopilot provides self-synchronization within the yaw channel computer. The synchronization provides a null output from the torquer amplifier to the rudder electrohydraulic transfer valve. With pitch and roll axes circuit breakers also closed, synchronization to airplane magnetic heading, as sensed by the directional gyro, is provided within the yaw channel computer by a heading synchronizer. The heading reference output signal is routed to the roll channel computer.

(2) Yaw Damper

(a) The yaw damper mode is engaged when yaw axis ac and dc circuit breakers are closed and the servos engage lever on the automatic pilot controller is moved to yaw damper. The servos engage lever is held at yaw damper if all yaw axis engage path interlock requirements are met. The yaw channel computer provides rudder command signals to damper the airplane dutch roll characteristics during manually and automatically controlled flight. Because of the rudder hydraulic and linkage tie-ins with the manual controls, automatic yaw damper control actions are not reflected at the rudder pedals. Further, the pilot can maneuver the airplane in a normal manner through the rudder pedals with no opposing force or action from the yaw damper.

(b) With pitch and roll axes circuit breakers closed, the yaw channel computer also provides rudder command signals to assist turn maneuvers.

(3) Autopilot

(a) The autopilot mode is engaged when yaw axis, pitch and roll axes, and air data circuit breakers are closed and the servos engage lever is set at autopilot. This continues yaw damper operation and also engages the roll and pitch axes. The yaw, roll, and pitch axes are series interlocked for autopilot control. When an interlock interruption occurs in any axis, the autopilot mode is automatically disengaged. If the pitch or roll axis is malfunctioning, the servos engage lever drops to yaw damper position and the autopilot off light comes on as an indication to the pilot. The light remains on until one of the autopilot release buttons is pressed.

(b) During the approach phase of ILS operation, the yaw channel computer receives a roll command to rudder signal that compensates for long-term airplane heading asymmetries such as loss of an engine. In addition, a heading synchronizer in the yaw computer module receives heading signals from the directional gyro and provides heading reference and heading error data to the roll channel computer for heading hold functions.

B. Roll Axis

(1) Synchronization

(a) With pitch and roll circuit breakers closed and power applied, the autopilot provides continuous synchronization to airplane roll attitude and magnetic heading. This synchronization provides a null output from the aileron servo amplifier to the aileron servo drive motor.

(2) Roll Axis Engage

(a) The roll axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot if all engage path interlock requirements are met.

(b) If the roll axis is engaged when the aircraft is at a roll angle (up to 35 degrees), the airplane automatically returns smoothly to a wings-level condition. When the airplane roll angle reduces to less than 6 degrees, the autopilot automatically couples the airplane to the compass heading (compass system).

(c) Heading hold is initiated with the navigation selector switch on the automatic pilot controller at turn knob and the turn knob at detent, heading hold is automatically established when airplane bank angle is less than 6 degrees.

(d) Automatic disengagement of the autopilot mode occurs when the roll axis monitor detects a malfunction within the roll axis. The servos engage lever drops to yaw damper and the autopilot off light comes on as an indication to the pilot. The pitch and yaw axes may be operated by using the split-axes servo switches (see paragraph D).

(3) Turn Knob

(a) The turn knob, located on the automatic pilot controller, is the primary roll control mode. The knob provides a manual turn control function for changing airplane heading. The turn knob must be in detent to engage the autopilot.

(b) The turn knob operates through the roll axis (aileron channel) to establish and hold the desired bank angle required to initiate a heading change. The degree and direction of bank angle is proportional to the amount and direction of turn knob rotation. When the turn knob is moved from detent, the roll axis automatically decouples from the heading reference. As long as the turn knob is left out of detent, the airplane remains in a turn at the commanded bank angle. When the turn knob is returned to detent, the airplane returns to wings level and is recoupled to the heading reference which exists when bank angle becomes than 6 degrees. Operation of the turn knob takes priority over any lateral control mode.

(4) Heading Select

(a) The heading select mode operates through the roll axis to establish and follow a chosen heading set on the course indicator or equivalent heading display. The heading select cursor on the indicator is positioned at the desired heading by using the heading select sync knob. With the navigation selector switch set at heading select, the airplane is automatically banked at a controlled roll rate up to a limited bank angle, to execute a turn toward the selected heading. As this heading is approached, the airplane is smoothly brought to wings-level. The airplane is aligned with the selected heading and is directed to maintain that heading until new commands are given to the autopilot.

(5) Localizer/Omnirange

(a) The roll channel computer provides aileron control in response to lateral radio signals (VOR and ILS) if the navigation selector switch is rotated to LOC/VOR and the navigation receiver is turned to the proper frequency. Desired omniradial heading or inbound runway heading must be set on the pictorial deviation indicator.

(b) Automatic beam capture is initiated by the pilot establishing an appropriate intercept heading using either the turn knob or heading select move. After the airplane rolls out on the intercept course, rotating the navigation selector switch to LOC/VOR establishes heading hold until lateral beam intercept.

(c) At beam intercept, the airplane turns toward the transmitting station at a limited bank angle that is a function of beam error, rate of change of beam error (ILS only), and course (runway) heading error. When the airplane attains the selected radial at beam center (on-course) the autopilot automatically integrates for crosswind correction. As the airplane approaches the zone-of-confusion above the VOR transmitter, interlocks decouple the beam signal, and the airplane is directed to fly at the drift-corrected radial heading. After passing the VOR station, the beam is again switched into roll command circuitry and the autopilot tracks the outbound radial.

(6) ILS

(a) With the navigation selector switch set to ILS at a specified beam error, glide path control is initiated. The pitch channel computer controls descent to glide path beam center channel while the roll computer maintains the airplane on beam center to minimum altitude or disengagement.

(b) Interlocks prevent selection of ILS unless the pitch axis is engaged and appropriate radio receiver is tuned to ILS frequency. The navigation selector switch will not hold in ILS and glide path capture is prevented.

(7) Auxiliary Navigation Control (Optional)

The autopilot roll axis can provide automatic control in response to track error and cross-track deviation information received from an auxiliary navigation or inertial guidance system to maintain a selected ground track or sequence of ground tracks. Auxiliary navigation or inertial navigation is engaged by pressing and rotating the navigation selector switch to AUX NAV after setting the initial conditions in the auxiliary navigation or inertial controller. Upon engagement, the airplane is automatically turned to intercept auxiliary navigation track.

C. Pitch Axis

(1) Synchronization

(a) With pitch and roll circuit breakers closed and power applied, the autopilot provides continuous synchronization to airplane pitch attitude, vertical speed, and altitude. This synchronization provides a null output from the elevator servo amplifier to the elevator servo drive motor prior to engagement.

(2) Pitch Axis Engage

(a) The pitch axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot if all engage path interlock requirements are met.

(b) When engaged, the pitch axis provides a vertical speed hold function. This is the primary pitch control mode. This mode adjusts the pitch attitude of the airplane to maintain the vertical speed existing when the pitch axis was engaged. The vertical speed hold function continues until changed by use of the vertical speed wheel on the automatic pilot controller.

(c) Automatic disengagement of autopilot control occurs when the pitch axis monitor detects a malfunction within the pitch axis. The servos engage lever drops to yaw damper and the autopilot off light comes on as an indication to the pilot. The yaw and roll axes may be operated by using the split-axes servo switches (see paragraph D).

(3) Vertical Speed Control

(a) The detent (center) position of the vertical speed wheel is altitude hold (zero vertical speed). During synchronization, the motor-driven vertical speed wheel follows up to the vertical speed of the airplane, providing a vertical speed reference for the vertical speed hold function at engagement.

(b) When the vertical speed wheel is moved out of detent, the airplane assumes, and adjusts as required, a pitch attitude to hold the commanded vertical speed. The pilot observes the rate of climb or descent on the vertical speed indicator and manually adjusts the vertical speed wheel to obtain the desired vertical speed. The pitch selector switch returns to vertical speed when the vertical speed wheel is manually moved. The navigation selector switch returns to turn knob when the airplane is under glide path control mode if the vertical speed knob is manually moved. If the system is in the glide path extension mode, and was manually or automatically engaged to this mode, manual movement of the vertical speed wheel reverts the system to the turn knob and/or vertical speed modes.

(4) Altitude Hold

(a) Altitude hold is established when the vertical speed wheel is at altitude hold (zero vertical speed). The airplane altitude existing when the vertical speed wheel is returned to the detent (altitude hold) position is maintained until a change in vertical speed is commanded.

(5) Pitch Damp

(a) When the pitch selector switch is pressed and rotated to the pitch damp position, the pitch damp mode is initiated. During this mode, which is used for turbulence penetration, automatic pitch trim is disconnected. Pitch trim is accomplished by manual actuation of the horizontal stabilizer controls. A "soft" pitch attitude damping function is provided by the autopilot to minimize pitch deviations. There is no vertical gyro pitch attitude reference during operation of pitch damp mode.

(6) Glide Path Control - Automatic

(a) The autopilot pitch axis provides automatic glide path control from signals received from a glide path receiver. The system automatically captures the glide path beam when the pitch axis is engaged, the glide path receiver is tuned to an ILS frequency, and the navigation selector switch is at ILS. At glide path capture the pitch selector switch returns to vertical speed if the switch was at another position.

(b) A 10-second capture period begins at glide path capture. During this period, a fixed vertical speed command is applied to the pitch channel computer, causing the airplane to descend at approximately 700 feet per minute. The vertical speed wheel follows up to this commanded rate of descent.

(c) After the 10-second capture period terminates, the airplane is in the glide path control phase. In this phase, the airplane follows the glide path beam.

(d) The vertical speed wheel follows up to the rate of descent during the control phase. Heading, localizer, and glide path gain programming are initiated as a function of radio altimeter altitude (analog dc output). If the radio altimeter malfunctions, localizer and glide path gains are programmed at glide path capture to compensate for ILS beam convergence. The control phase ends where the pilot terminates the automatic approach to land the airplane manually.

(7) Glide Path Extension - Manual

The glide path extension mode is manually engaged by placing the pitch selector switch at G/P EXT. This mode can be used by the pilot to initiate glide path second-stage gain programming only when glide path is energized (capture +10 seconds), the radio altimeter has failed or is not connected to the autopilot, and the middle marker beacon is not passed. If the radio altimeter is disabled or not installed, glide path gains are second-stage programmed automatically upon interception of the middle marker beacon.

D. Split-Axes Operation

(1) The three autopilot (split-axes) servo switches, located on the flight instrument panel provide independent cutoff of roll, pitch, and yaw control functions of the autopilot. In this manner, the pilot may use manual control in one or two axes while the autopilot retains control in the remaining engaged axes. In addition, even though a malfunction occurs in one or more control channels a portion of the autopilot may still be used. Aplit-axes operation also provides approach operation with manual pitch axis control.

(2) The roll and pitch channels can be split off individually, but the yaw channel can not. If the yaw channel is to be split off; both rudder and aileron servo switches must be placed in their off positions. This is necessary due to roll channel dependence on yaw damper for proper performance.

AUTOPILOT - DESCRIPTION AND OPERATION

1. Description

A. The autopilot is that portion of the auto flight control system which operates the flight control surfaces of the airplane as needed to maintain straight and level flight or to maneuver in response to pilot commands. Operating modes can be selected to provide automatic control of:

(1) Yaw damping

(2) Constant altitude

(3) Coordinated turn

(4) Vertical speed

(5) Pitch damping during turbulence

(6) Preselected compass heading

(7) Omnirange flying and localizer guidance

(8) ILS control

(9) Constant indicated airspeed or mach number.

B. Yaw Damper

(1) The yaw damper function can be engaged separately to provide necessary yaw damping during manual flying. Yaw damper control is not reflected at the rudder pedals.

C. Autopilot Control

(1) When the complete system is engaged, the autopilot controls the airplane in roll, pitch, and yaw axes. The existing attitude and directional reference is automatically maintained.

D. System Components (See Figure 1.)

Component	Function
(1) Autopilot Mode Annunciator	Provides visual display of radio guidance/approach mode controlling autopilot.

Component	Function
(2) Automatic Pilot Controller	Provides fingertip controls to enable the captain and first officer to engage the autopilot, select the various modes of operation, and to initiate maneuvering commands.
(3) Automatic Pilot Indicator	Provides visual indication of aileron and elevator servo drive trim conditions and output of yaw actuator position transducer. Lights indicate autopilot off, glide path armed, auto trim off.
(4) Autopilot Release Switches	Provide disengagement of the roll and pitch axes of the autopilot.
(5) Accelerometers (six required)	Translate acceleration in yaw, roll, and pitch axes into electrical signals for damping short-period attitude changes.
(6) Servo Drives and Brackets (two required)	Initiate movement of the aileron and elevator in response to amplified signals from the roll and pitch channels.
(7) Yaw Axis Electrohydraulic Transfer Valve (part of rudder hydraulic power package)	Provides the means for yaw channel input to the main control valve in the rudder hydraulic power package.
(8) Roll Channel Computer	Provides roll axis interlock; computes and shapes error and command signals to drive the aileron servo drive.
(9) Yaw Channel Computer	Provides automatic stability augmentation and turn coordination in response to command signals from the autopilot sensing and control devices.
(10) Pitch Channel Computer	Provides pitch axis interlock; computes and shapes error and command signals to drive the elevator servo drive.

Component	Function
(11) Air Data Computer	Provides signals for autopilot vertical speed, altitude hold, Mach Q_c/p data, and airspeed (Q) switching of autopilot command parameters, and airspeed and Mach number data.

2. Operation

A. Yaw Axis

(1) Synchronization

(a) With yaw axis circuit breakers closed and power applied, the autopilot provides self-synchronization within the yaw channel computer. The synchronization provides a null output from the torquer amplifier to the electrohydraulic transfer valve. With pitch and roll axes circuit breakers also closed, synchronization to airplane magnetic heading, as sensed by the directional gyro, is provided within the yaw channel computer by a heading synchronizer. The heading reference output signal is routed to the roll channel computer.

(2) Yaw Damper

(a) The yaw damper mode is engaged when yaw axis ac and dc circuit breakers are closed and the servos engage lever on the automatic pilot controller is moved to yaw damper position. The servos engage lever is held at the yaw damper position if all yaw axis engage path interlock requirements are met. The yaw channel computer provides rudder command signals to dampen the airplane dutch roll characteristics during manually and automatically controlled flight. Because of the rudder hydraulic and linkage tie-ins with the manual controls, yaw damper control actions are not reflected at the rudder pedals. Further, the pilot can maneuver the airplane in a normal manner through the rudder pedals with no opposing force or action from the yaw damper.

(b) With pitch and roll axes circuit breakers closed, and the autopilot mode engaged, the yaw channel computer also provides rudder command signals to assist turn maneuvers.

(3) Autopilot

(a) The autopilot mode is engaged when yaw axis, pitch and roll axes, and air data circuit breakers are closed and the servos engage lever is set at autopilot. This continues yaw damper operation and also

engages the roll and pitch axes. The yaw, roll, and pitch axes are series interlocked for autopilot control. When an interlock interruption occurs in any axis, the autopilot mode is automatically disengaged. If the pitch or roll axis is malfunctioning, the servos engage lever drops to yaw damper position and the autopilot off light comes on as an indication to the pilot. The light remains on until one of the autopilot release buttons is pressed.

(b) During the approach phase of ILS operation, the yaw channel computer receives a roll command to rudder signal that compensates for long-term airplane heading asymmetrics such as loss of an engine. In addition, a heading synchronizer in the yaw computer module receives heading signals from the directional gyro and provides heading reference and heading error data to the roll channel computer for heading hold functions.

B. Roll Axis

(1) Synchronization

(a) With pitch and roll circuit breakers closed and power applied, the autopilot provides continuous synchronization to airplane roll attitude and magnetic heading. Th.s synchronization provides a null output from the aileron servo amplifier to the aileron servo drive motor.

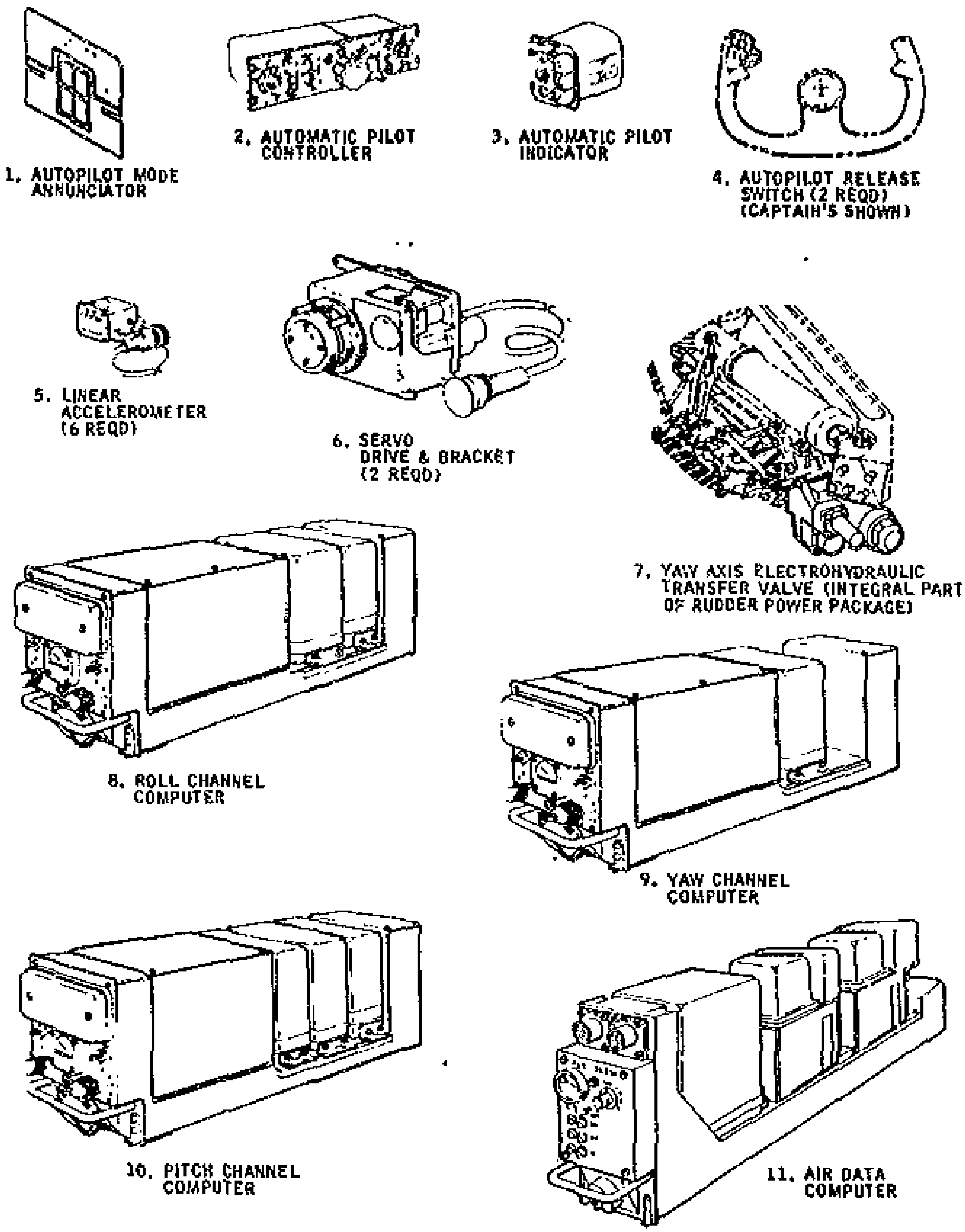
(2) Roll Axis Engage

(a) The roll axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot position if all engage path interlock requirements are met.

(b) If the roll axis is engaged when the aircraft is at a roll angle (up to 35 degrees), the airplane automatically returns smoothly to a wings-level condition. When the airplane roll angles reduces to less than 6 degrees, the autopilot automatically couples the airplane to the compass heading (compass system).

(c) Heading hold is initiated with the navigation selector switch on the automatic pilot controller at turn knob and the turn knob at detent, heading hold is automatically established when airplane bank angle is less than 6 degrees.

(d) Automatic disengagement of the autopilot mode occurs when the roll axis monitor detects a malfunction within the roll axis. The servos engage lever drops to yaw damper, and the autopilot off light comes on as an indication to the pilot.



Autopilot System Components
Figure 1

(3) Turn Knob

(a) The turn knob located on the automatic pilot controller is the primary roll control mode. The knob provides a manual turn control function for changing airplane heading. The turn knob must be in detent to engage the autopilot.

(b) The turn knob operates through the roll axis (aileron channel) to establish and hold the desired bank angle required to initiate a heading change. The degree and direction of bank angle is proportional to the amount and direction of turn knob rotation. When the turn knob is moved from detent, the roll axis automatically decouples from the heading reference. As long as the turn knob is left out of detent, the airplane remains in a turn at the commanded bank angle. When the turn knob is returned to the detent position, the airplane returns to wings level and is recoupled to the heading reference which exists when bank angle becomes less than 6 degrees. Operation of the turn knob takes priority over any lateral control mode.

(4) Heading Select

(a) The heading select mode operates through the roll axis to establish and follow a chosen heading set on the course indicator or equivalent heading display. The heading select cursor on the indicator is positioned at the desired heading by using the heading select sync knob. With the navigation selector switch set to heading select, the airplane is automatically banked at a controlled roll rate up to a limited bank angle to execute a turn toward the selected heading. As this heading is approached, the airplane is smoothly brought to wings-level. The airplane is aligned with the selected heading and is directed to maintain that heading until new commands are given to the autopilot.

(5) Localizer/Omnirange

(a) The roll channel computer provides aileron control in response to lateral radio signals (VOR and ILS) if the navigation selector switch is rotated to LOC/VOR and the navigation receiver is tuned to the proper frequency. Desired omniradial heading or inbound runway heading must be set on the pictorial deviation indicator.

(b) Automatic beam capture is initiated by the pilot establishing an appropriate intercept heading, using either the turn knob or heading select mode. After the airplane rolls out on the intercept course, rotating the navigation selector switch to LOC/VOR establishes heading hold until lateral beam intercept.

(c) At beam intercept, the airplane turns toward the transmitting station at a limited bank angle that is a function of beam error, rate of change of beam error (ILS only), and course runway heading error. When the airplane attains the selected radial at beam center

(on-course) the autopilot automatically integrates for crosswind correction. As the airplane approaches the zone-of-confusion above the VOR transmitter, interlocks decouple the beam signal, and the airplane is directed to fly at the drift-corrected radial heading. After passing the VOR station, the beam is again switched into roll command circuitry, and the autopilot tracks the outbound radial.

(6) ILS

(a) With the navigation selector switch set to ILS at a specified beam error, glide path control is initiated. The pitch channel computer controls descent to glide path beam center while the roll channel computer maintains the airplane on localizer beam center to minimum altitude or disengagement.

(b) Interlocks prevent selection of ILS unless the pitch axis is engaged and appropriate radio receiver is tuned to ILS frequency. The navigation selector switch will not hold in ILS, and glide path capture is prevented.

(7) Auxiliary Navigation Control (Optional)

The autopilot roll axis provides automatic control in response to track error and cross track deviation information received from an auxiliary navigation system to maintain a selected ground track or sequence of ground tracks. Auxiliary navigation is engaged by pressing and rotating the navigation selector switch to AUX NAV after setting the initial conditions in the auxiliary navigation controller. Upon engagement, the airplane will automatically be turned to intercept auxiliary navigation track. Auxiliary navigation control of the airplane is implemented only in airplanes equipped with auxiliary navigation systems.

C. Pitch Axis

(1) Synchronization

(a) With pitch and roll circuit breakers closed and power applied, the autopilot provides continuous synchronization of airplane pitch attitude, vertical speed, and altitude. This synchronization provides a null output from the elevator servo amplifier to the elevator servo drive motor prior to engagement.

(2) Pitch Axis Engage

(a) The pitch axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot if all engage path interlock requirements are met.

(b) When engaged, the pitch axis provides a vertical speed hold function. This is the primary pitch control mode. It adjusts the pitch attitude of the airplane to maintain the vertical speed existing when the pitch axis was engaged. The vertical speed hold function continues until changed by use of the vertical speed wheel on the automatic pilot controller.

(c) Automatic disengagement of autopilot control occurs when the pitch axis monitor detects a malfunction within the pitch axis. The servos engage lever drops to yaw damper and the autopilot off light comes on as an indication to the pilot.

(3) Vertical Speed Control

(a) The detent (center) position of the vertical speed wheel is altitude hold (zero vertical speed). During synchronization, the motor-driven vertical speed wheel follows up to the vertical speed of the airplane, providing a vertical speed reference for the vertical speed hold function at engagement.

(b) When the vertical speed wheel is moved out of detent, the airplane assumes (and adjusts as required) a pitch attitude to hold the commanded vertical speed. The pilot observes the rate of climb (or descent) on the vertical speed indicator and manually adjusts the vertical speed wheel to obtain the desired vertical speed. The pitch selector switch returns to vertical speed when the vertical speed wheel is manually moved. The navigation selector switch returns to turn knob when the airplane is under glide path control mode if the vertical speed knob is manually moved. If the system is in the glide path extension mode (and was manually or automatically engaged to this mode), manual movement of the vertical speed wheel reverts the system to the turn knob and vertical speed modes.

(4) Altitude Hold

(a) Altitude hold is established when the vertical speed wheel is at altitude hold (zero vertical speed). The airplane altitude existing when the vertical speed wheel is returned to the detent (altitude hold) position is maintained until a change in vertical speed is commanded.

(5) Pitch Damp

(a) When the pitch selector switch is pressed and rotated to the pitch damp position, the pitch damp mode is initiated. During this mode, which is used for turbulence penetration, automatic pitch trim is disconnected. Pitch trim is accomplished by manual actuation of the horizontal stabilizer controls. A "soft" pitch attitude damping function is provided by the autopilot to minimize pitch rate deviations. There is no vertical gyro pitch attitude reference during operation of pitch damp mode.

(6) Glide Path Control - Automatic

(a) The autopilot pitch axis provides automatic glide path control from signals received from a glide path receiver. The system automatically captures the glide path beam when the pitch axis is engaged, the glide path receiver is tuned to an ILS frequency, and the navigation selector switch is at ILS. At glide path capture the pitch selector switch returns to vertical speed if the switch was at another position.

(b) A 10-second capture period begins at glide path capture. During this period, a fixed vertical speed command is applied to the pitch channel computer, causing the airplane to descend at approximately 700 feet per minute. The vertical speed wheel follows up to this commanded rate of descent.

(c) After the 10-second capture period terminates, the airplane is in the glide path control phase. In this phase, the airplane follows the glide path beam.

(d) The vertical speed wheel follows up to the rate of descent during the control phase. Heading, localizer, and glide path gain programing are initiated as a function of radio altimeter altitude (analog dc output). If the radio altimeter malfunctions, localizer and glide path gains are programed at glide path capture to compensate for ILS beam convergence. The control phase ends when the pilot terminates the automatic approach to land the airplane manually.

(7) Glide Path Extension

The glide path extension mode is manually engaged by placing the pitch selector switch at G/P EXT. This mode can be used by the pilot to initiate glide path second stage gain programing only when glide path is energized (capture +10 seconds), the radio altimeter has failed or is not connected to the autopilot, and the middle marker beacon is not passed. If the radio altimeter is disabled or not installed, glide path gains are second-stage programed automatically upon interception of the middle marker beacon.

(8) IAS Hold

(a) The IAS (indicated airspeed) hold mode is engaged by moving the pitch selector switch to the IAS hold position. The indicated airspeed existing at the time of engagement is maintained by automatic adjustment of the airplane pitch attitude.

(b) With the pitch axis engaged, the vertical speed hold function automatically controls vertical speed. When the desired indicated airspeed is attained, the pitch selector switch is rotated to the IAS

hold position. Automatic elevator control adjusts pitch attitude to maintain the desired airspeed; throttle adjustment will maintain rate of climb or descent.

(c) When the desired altitude is reached, moving the vertical speed wheel to the detent disengages IAS hold. The pitch selector switch returns to the vertical speed position and altitude hold is engaged.

(9) Mach Hold

(a) The Mach hold mode is engaged by moving the pitch selector switch to the Mach hold position. The Mach number existing at the time of engagement is maintained by automatic adjustment of the airplane pitch attitude. As the airplane climbs at a constant speed, the Mach number increases with altitude. When the desired Mach number is attained, the pitch selector switch is pressed and rotated to the Mach hold position. The airplane then climbs at a decreasing airspeed to maintain the desired Mach number. Moving the vertical speed wheel to the detent disengages the Mach hold mode. The pitch selector switch returns to the vertical speed position and the altitude hold mode is engaged.

AUTOPILOT - DESCRIPTION AND OPERATION

1. Description

A. The autopilot is that portion of the auto flight control system which operates the flight control surfaces of the airplane as needed to maintain straight and level flight or to maneuver in response to pilot commands. Operating modes can be selected to provide automatic control of:

(1) Yaw damping

(2) Constant altitude

(3) Coordinated turn

(4) Vertical speed

(5) Pitch damping during turbulence

(6) Preselected compass heading

(7) Omnirange flying and localizer guidance

(8) ILS control.

B. Yaw Damper

(1) The yaw damper function can be engaged separately to provide necessary yaw damping during manual flying. Yaw damper control is not reflected at the rudder pedals.

C. Autopilot Control

(1) When the complete system is engaged, the autopilot controls the airplane in roll, pitch, and yaw axes. The existing attitude and directional reference is automatically maintained.

D. System Components (See Figure 1.)

Component	Function
(1) Autopilot Mode Annunciator	Provides visual display of radio guidance/approach mode controlling autopilot.
(2) Automatic Pilot Controller	Provides fingertip controls to enable the captain and first officer to engage the autopilot, select the various modes of operation, and to initiate maneuvering commands.

	Component	Function
(3)	Automatic Pilot Indicator	Provides visual indication of aileron and elevator servo drive trim conditions and output of yaw actuator position transducer. Lights indicate autopilot off, glide path armed, auto trim off.
(4)	Autopilot Release Switches	Provide disengagement of the roll and pitch axes of the autopilot.
(5)	Accelerometers (six required)	Translate acceleration in yaw, roll, and pitch axes into electrical signals for damping short-period attitude changes.
(6)	Servo Drives and Brackets (two required)	Initiate movement of the aileron, and elevator in response to amplified signals from the roll and pitch channels.
(7)	Yaw Axis Electrohydraulic Transfer Valve (part of rudder hydraulic power package)	Provides the means for yaw channel input to the main control valve in the rudder hydraulic power package.
(8)	Roll Channel Computer	Provides roll axis interlock; computes and shapes error and command signals to drive the aileron servo drive.
(9)	Yaw Channel Computer	Provides automatic stability augmentation and turn coordination in response to command signals from the autopilot sensing and control devices.
(10)	Pitch Channel Computer	Provides pitch axis interlock; computes and shapes error and command signals to drive the elevator servo drive.

2. Operation

A. Yaw Axis

(1) Synchronization

(a) With yaw axis circuit breakers closed and power applied, the autopilot provides self-synchronization within the yaw channel computer. The synchronization provides a null output from the torquer amplifier to the electrohydraulic transfer valve. With pitch and roll axes circuit breakers also closed, synchronization to airplane magnetic heading, as sensed by the directional gyro, is provided within the yaw channel computer by a heading synchronizer. The heading reference output signal is routed to the roll channel computer.

(2) Yaw Damper

(a) The yaw damper mode is engaged when yaw axis ac and dc circuit breakers are closed and the servos engage lever on the automatic pilot controller is moved to yaw damper position. The servos engage lever is held at the yaw damper position if all yaw axis engage path interlock requirements are met. The yaw channel computer provides rudder command signals to dampen the airplane dutch roll characteristics during manually and automatically controlled flight. Because of the rudder hydraulic and linkage tie-ins with the manual controls, yaw damper control actions are not reflected at the rudder pedals. Further, the pilot can maneuver the airplane in a normal manner through the rudder pedals with no opposing force or action from the yaw damper.

(b) With pitch and roll axes circuit breakers closed, and the autopilot mode engaged, the yaw channel computer also provides rudder command signals to assist turn maneuvers.

(3) Autopilot

(a) The autopilot mode is engaged when yaw axis, pitch and roll axes, and central air data circuit breakers are closed and the servos engage lever is set at autopilot. This continues yaw damper operation and also engages the roll and pitch axes. The yaw, roll, and pitch axes are series interlocked for autopilot control. When an interlock interruption occurs in any axis, the autopilot mode is automatically disengaged. If the pitch or roll axis is malfunctioning, the servos engage lever drops to yaw damper position and the autopilot off light comes on as an indication to the pilot. The light remains on until one of the autopilot release buttons is pressed.

(b) During the approach phase of ILS operation, the yaw channel computer receives a roll command to rudder signal that compensates for long-term airplane heading asymmetries such as loss of an engine. In

addition, a heading synchronizer in the yaw computer module receives heading signals from the directional gyro and provides heading reference and heading error data to the roll channel computer for heading hold functions.

B. Roll Axis

(1) Synchronization

(a) With pitch and roll circuit breakers closed and power applied, the autopilot provides continuous synchronization to airplane roll attitude and magnetic heading. This synchronization provides a null output from the aileron servo amplifier to the aileron servo drive motor.

(2) Roll Axis Engage

(a) The roll axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot position if all engage path interlock requirements are met.

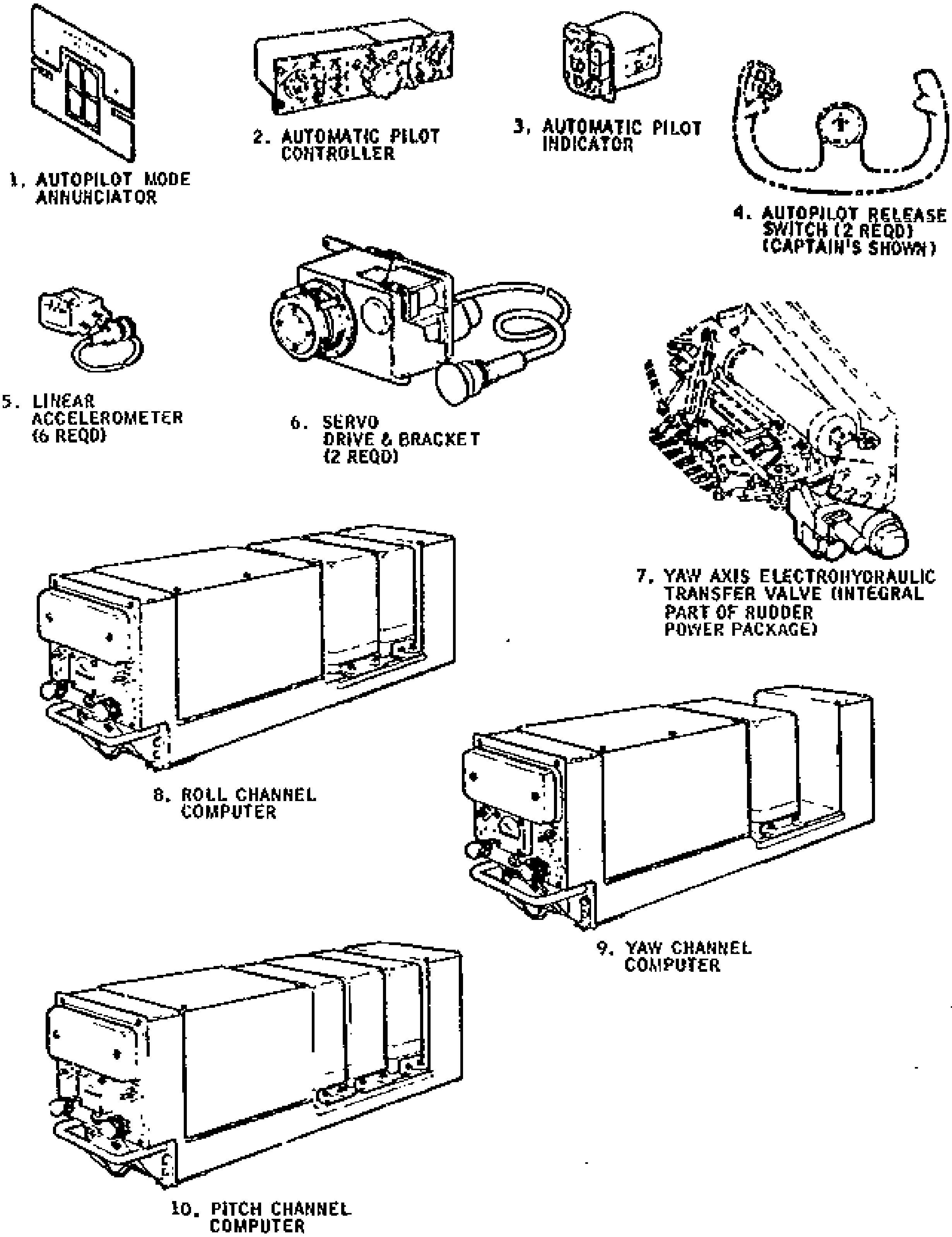
(b) If the roll axis is engaged when the aircraft is at a roll angle (up to 35 degrees), the airplane automatically returns smoothly to a wings-level condition. When the airplane roll angle reduces to less than 6 degrees, the autopilot automatically couples the airplane to the compass heading (compass system).

(c) Heading hold is initiated with the navigation selector switch on the automatic pilot controller at turn knob and the turn knob at detent, heading hold is automatically established when airplane bank angle is less than 6 degrees.

(d) Automatic disengagement of the autopilot mode occurs when the roll axis monitor detects a malfunction within the roll axis. The servos engage lever drops to yaw damper, and the autopilot off light comes on as an indication to the pilot.

(3) Turn Knob

(a) The turn knob located on the automatic pilot controller is the primary roll control mode. The knob provides a manual turn control function for changing airplane heading. The turn knob must be in detent to engage the autopilot.



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Autopilot System Components
Figure 1

(b) The turn knob operates through the roll axis (aileron channel) to establish and hold the desired bank angle required to initiate a heading change. The degree and direction of bank angle is proportional to the amount and direction of turn knob rotation. When the turn knob is moved from detent, the roll axis automatically decouples from the heading reference. As long as the turn knob is left out of detent, the airplane remains in a turn at the commanded bank angle. When the turn knob is returned to the detent position, the airplane returns to wings level and is recoupled to the heading reference which exists when bank angle becomes less than 6 degrees. Operation of the turn knob takes priority over any lateral control mode.

(4) Heading Select

(a) The heading select mode operates through the roll axis to establish and follow a chosen heading set on the course indicator or equivalent heading display. The heading select cursor on the indicator is positioned at the desired heading by using the heading select sync knob. With the navigation selector switch set to heading select, the airplane is automatically banked at a controlled roll rate up to a limited bank angle to execute a turn toward the selected heading. As this heading is approached, the airplane is smoothly brought to wings-level. The airplane is aligned with the selected heading and is directed to maintain that heading until new commands are given to the autopilot.

(5) Localizer/Omnirange

(a) The roll channel computer provides aileron control in response to lateral radio signals (VOR and ILS) if the navigation selector switch is rotated to LOC/VOR and the navigation receiver is tuned to the proper frequency. Desired omniradial heading or inbound runway heading must be set on the pictorial deviation indicator.

(b) Automatic beam capture is initiated by the pilot establishing an appropriate intercept heading, using either the turn knob or heading select mode. After the airplane rolls out on the intercept course, rotating the navigation selector switch to LOC/VOR establishes heading hold until lateral beam intercept.

(c) At beam intercept, the airplane turns toward the transmitting station at a limited bank angle that is a function of beam error, rate of change of beam error (ILS only), and course runway heading error. When the airplane attains the selected radial at beam center (on-course) the autopilot automatically integrates for crosswind correction. As the airplane approaches the zone-of-confusion above the VOR transmitter, interlocks decouple the beam signal, and the airplane is directed to fly at the drift-corrected radial heading. After passing the VOR station, the beam is again switched into roll command circuitry, and the autopilot tracks the outbound radial.

(6) ILS

(a) With the navigation selector switch set to ILS at a specified beam error, glide path control is initiated. The pitch channel computer controls descent to glide path beam center while the roll channel computer maintains the airplane on localizer beam center to minimum altitude or disengagement.

(b) Interlocks prevent selection of ILS unless the pitch axis is engaged and appropriate radio receiver is tuned to ILS frequency. The navigation selector switch will not hold in ILS, and glide path capture is prevented.

(7) Auxiliary Navigation Control (Optional)

The autopilot roll axis provides automatic control in response to track error and cross track deviation information received from an auxiliary navigation system to maintain a selected ground track or sequence of ground tracks. Auxiliary navigation is engaged by pressing and rotating the navigation selector switch to AUX NAV after setting the initial conditions in the auxiliary navigation controller. Upon engagement, the airplane will automatically be turned to intercept auxiliary navigation track. Auxiliary navigation control of the airplane is implemented only in airplanes equipped with auxiliary navigation systems.

C. Pitch Axis

(1) Synchronization

(a) With pitch and roll circuit breakers closed and power applied, the autopilot provides continuous synchronization of airplane pitch attitude, vertical speed, and altitude. This synchronization provides a null output from the elevator servo amplifier to the elevator servo drive motor prior to engagement.

(2) Pitch Axis Engage

(a) The pitch axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot if all engage path interlock requirements are met.

(b) When engaged, the pitch axis provides a vertical speed hold function. This is the primary pitch control mode. It adjusts the pitch attitude of the airplane to maintain the vertical speed existing when the pitch axis was engaged. The vertical speed hold function continues until changed by use of the vertical speed wheel on the automatic pilot controller.

(c) Automatic disengagement of autopilot control occurs when the pitch axis monitor detects a malfunction within the pitch axis. The servos engage lever drops to yaw damper and the autopilot off light comes on as an indication to the pilot.

(3) Vertical Speed Control

(a) The detent (center) position of the vertical speed wheel is altitude hold (zero vertical speed). During synchronization, the motor-driven vertical speed wheel follows up to the vertical speed of the airplane, providing a vertical speed reference for the vertical speed hold function at engagement.

(b) When the vertical speed wheel is moved out of detent, the airplane assumes (and adjusts as required) a pitch attitude to hold the commanded vertical speed. The pilot observes the rate of climb (or descent) on the vertical speed indicator and manually adjusts the vertical speed wheel to obtain the desired vertical speed. The pitch selector switch returns to vertical speed when the vertical speed wheel is manually moved. The navigation selector switch returns to turn knob when the airplane is under glide path control mode if the vertical speed knob is manually moved. If the system is in the glide path extension mode (and was manually or automatically engaged to this mode), manual movement of the vertical speed wheel reverts the system to the turn knob and vertical speed modes.

(4) Altitude Hold

(a) Altitude hold is established when the vertical speed wheel is at altitude hold (zero vertical speed). The airplane altitude existing when the vertical speed wheel is returned to the detent (altitude hold) position is maintained until a change in vertical speed is commanded.

(5) Pitch Damp

(a) When the pitch selector switch is pressed and rotated to the pitch damp position, the pitch damp mode is initiated. During this mode, which is used for turbulence penetration, automatic pitch trim is disconnected. Pitch trim is accomplished by manual actuati n of the horizontal stabilizer controls. A "soft" pitch attitude damping function is provided by the autopilot to minimize pitch rate deviations. There is no vertical gyro pitch attitude reference during operation of pitch damp mode.

(6) Glide Path Control - Automatic

(a) The autopilot pitch axis provides automatic glide path control from signals received from a glide path receiver. The system automatically captures the glide path beam when the pitch axis is engaged,

the glide path receiver is tuned to an ILS frequency, and the navigation selector switch is at ILS. At glide path capture the pitch selector switch returns to vertical speed if the switch was at another position.

(b) A 10-second capture period begins at glide path capture. During this period, a fixed vertical speed command is applied to the pitch channel computer, causing the airplane to descend at approximately 700 feet per minute. The vertical speed wheel follows up to this commanded rate of descent.

(c) After the 10-second capture period terminates, the airplane is in the glide path control phase. In this phase, the airplane follows the glide path beam.

(d) The vertical speed wheel follows up to the rate of descent during the control phase. Heading, localizer, and glide path gain programing are initiated as a function of radio altimeter altitude (analog dc output). If the radio altimeter malfunctions, localizer and glide path gains are programmed at glide path capture to compensate for ILS beam convergence. The control phase ends when the pilot terminates the automatic approach to land the airplane manually.

(7) Glide Path Extension

The glide path extension mode is manually engaged by placing the pitch selector switch at G/P EXT. This mode can be used by the pilot to initiate glide path second stage gain programing only when glide path is energized (capture +10 seconds), the radio altimeter has failed or is not connected to the autopilot, and the middle marker beacon is not passed. If the radio altimeter is disabled or not installed, glide path gains are second-stage programed automatically upon interception of the middle marker beacon.

AUTOPILOT - DESCRIPTION AND OPERATION

1. Description

A. The autopilot is that portion of the auto flight control system which operates the flight control surfaces of the airplane as needed to maintain straight and level flight or maneuver in response to pilot commands. Operating modes can be selected to provide automatic control of:

(1) Yaw damping

(2) Constant altitude

(3) Coordinated turn

(4) Vertical speed

(5) Pitch damping during turbulence

(6) Preselected compass heading

(7) Omnirange flying and localizer guidance

(8) ILS control

(9) Split-axes control

B. Yaw Damper

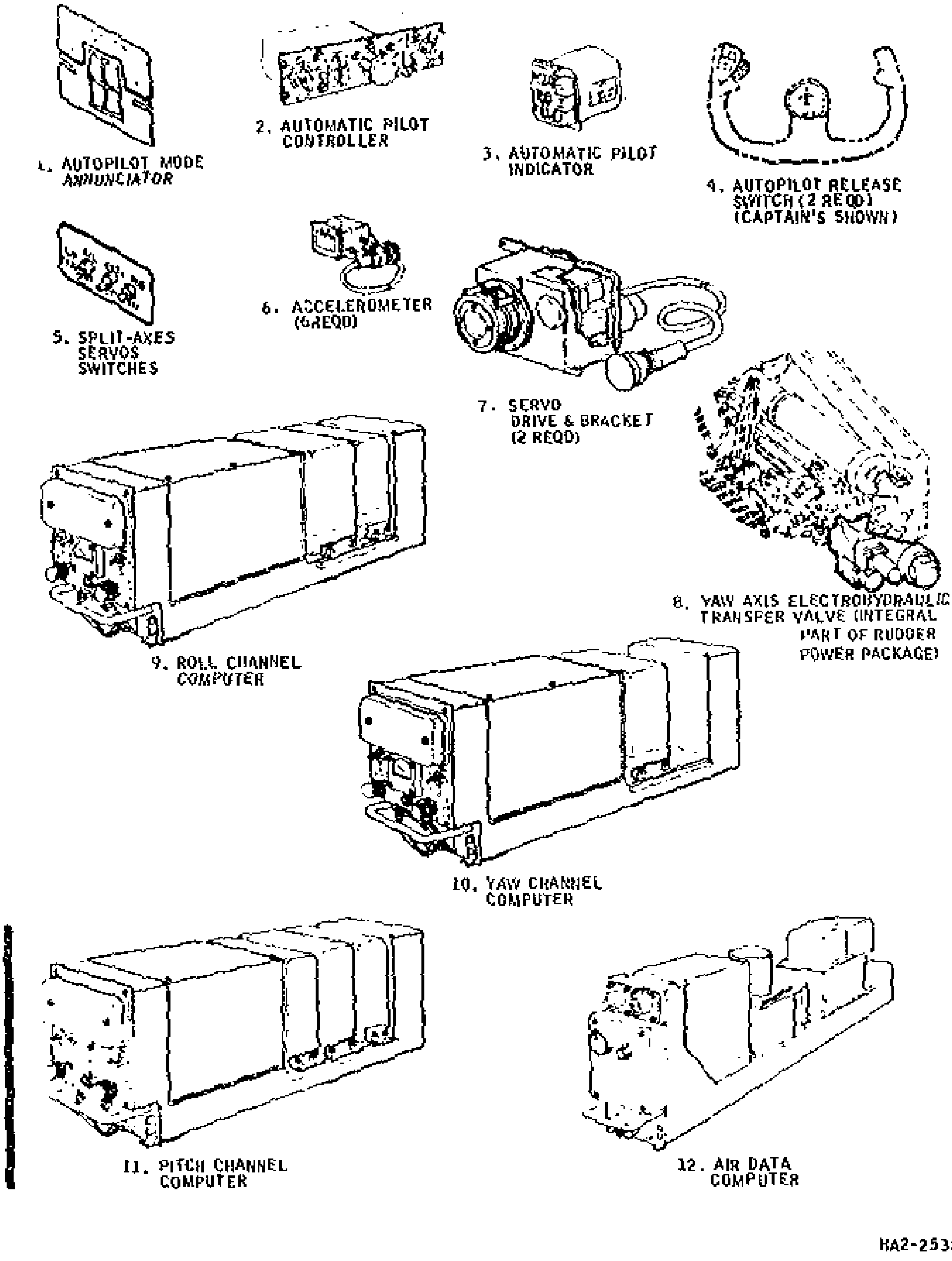
(1) The yaw damper function can be engaged separately to provide necessary yaw damping during manual flying. Yaw damper control is not reflected at the rudder pedals.

C. Autopilot Control

(1) When the complete system is engaged, the autopilot controls the airplane in roll, pitch, and yaw axes. The existing attitude and directional reference is automatically maintained.

D. System Components (See Figure 1.)

Component	Function
(1) Autopilot Mode Annunciator	Provides visual display of radio guidance/approach mode controlling autopilot.



Autopilot System Components
Figure 1

Component	Function
(2) Automatic Pilot Controller	Provides fingertip controls to enable the captain and first officer to engage the autopilot, select the various modes of operation, and to initiate maneuvering commands.
(3) Automatic Pilot Indicator	Provides visual indication of aileron and elevator servo drive trim conditions and output of yaw actuator position transducer. Lights indicate autopilot off, glide path armed, auto trim off.
(4) Autopilot Release Switches	Provide disengagement of the roll and pitch axes of the autopilot.
(5) Autopilot Servos (Split-Axes) Switches	Provide independent cutoff of yaw, roll, and pitch control functions.
(6) Accelerometers (six required)	Translate acceleration in yaw, roll, and pitch axes into electrical signals for damping short-period attitude changes.
(7) Servo Drives and Brackets (two required)	Initiate movement of the ailerons and elevator in response to amplified signals from the roll and pitch channels.
(8) Yaw Axis Electrohydraulic Transfer Valve (part of rudder hydraulic power package)	Provides the means for yaw channel input to the main control valve in the rudder hydraulic power package.
(9) Roll Channel Computer	Provides roll axis interlock; computes and shapes error and command signals to drive the aileron servo drive.
(10) Yaw Channel Computer	Provides automatic stability augmentation and turn coordination in response to command signals from the autopilot sensing and control devices.

Component	Function
(11) Pitch Channel Computer	Provides pitch axis interlock; computes and shapes error and command signals to drive the elevator servo drive.
(12) Air Data Computer	Provides signals for autopilot vertical speed, altitude hold, Mach Q_c/p data, and airspeed (Q) switching of autopilot command parameters.

2. Operation

A. Yaw Axis Modes of Operation

(1) Synchronization

(a) With yaw axis circuit breakers closed and power applied, the autopilot provides self-synchronization within the yaw channel computer. The synchronization provides a null output from the torquer amplifier to the rudder electrohydraulic transfer valve. With pitch and roll axes circuit breakers also closed, synchronization to airplane magnetic heading as sensed by the directional gyro is provided within the yaw channel computer by a heading synchronizer. The heading reference output signal is routed to the roll channel computer.

(2) Yaw Damper

(a) The yaw damper mode is engaged when yaw axis ac and dc circuit breakers are closed and the servos engage lever on the automatic pilot controller is moved to yaw damper position. The servos engage lever is held at the yaw damper position if all yaw axis engage path interlock requirements are met. The yaw channel computer provides rudder command signals to dampen the airplane dutch roll characteristics during manually and automatically controlled flight. Because of the rudder hydraulic and linkage tie-ins with the manual controls, automatic yaw damper control actions are not reflected at the rudder pedals. Further, the pilot can maneuver the airplane in a normal manner through the rudder pedals with no opposing force or action from the yaw damper.

(b) With the autopilot 115-volt ac circuit breaker closed and the autopilot mode engaged, the yaw channel computer also provides rudder command signals to assist turn maneuvers.

(3) Autopilot

(a) The autopilot mode is engaged when yaw axis, pitch and roll axes, and air data circuit breakers are closed and the servos engage lever is set at autopilot. This continues yaw damper operation and also engages the roll and pitch axes. The yaw, roll, and pitch axes are series interlocked for autopilot control. When an interlock interruption occurs in any axis the autopilot mode is automatically disengaged. If the pitch or roll axis is malfunctioning, the servos engage lever drops to yaw damper position, and the autopilot off light comes on as an indication to the pilot. The light remains on until one of the autopilot release buttons is pressed.

(b) During the approach phase of ILS operation, the yaw channel computer receives a roll command to rudder signal that compensates for long-term airplane heading asymmetries such as loss of an engine. In addition, a heading synchronizer in the yaw computer module receives heading signals from the directional gyro and provides heading reference and heading error data to the roll channel computer for heading hold functions.

B. Roll Axis

(1) Synchronization

(a) With pitch and roll axes circuit breakers closed and power applied, the autopilot provides continuous synchronization to airplane roll attitude and magnetic heading. This synchronization provides a null output from the aileron servo amplifier to the aileron servo drive motor.

(2) Roll Axis Engage

(a) The roll axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot position if all engage path interlock requirements are met.

(b) If the roll axis is engaged when the aircraft is at a roll angle up to 35 degrees, the airplane automatically returns smoothly to a wings-level condition. When the airplane roll angle reduces to less than 6 degrees, the autopilot automatically couples the airplane to the compass heading (compass system).

(c) Heading hold is initiated with the navigation selector switch on the automatic pilot controller at turn knob and the turn knob at detent, heading hold is automatically established when airplane bank angle is less than 6 degrees.

(d) Automatic disengagement of the autopilot mode occurs when the roll axis monitor detects a malfunction within the roll axis. The servos engage lever drops to yaw damper, and the autopilot off light comes on as an indication to the pilot. The yaw or pitch axes may be operated by using the split-axes servo switches (see paragraph D).

(3) Turn Knob

(a) The turn knob located on the automatic pilot controller is the primary roll control mode. The turn knob provides a manual turn control function for changing airplane heading. The turn knob must be in detent position to engagement of the autopilot.

(b) The turn knob operates through the roll axis (aileron channel) to establish and hold the desired bank angle required to initiate a heading change. The degree and direction of bank angle is proportional to the amount and direction of turn knob rotation. When the turn knob is moved from detent, the roll axis automatically decouples from the heading reference. As long as the turn knob is left out of detent, the airplane remains in a turn at the commanded bank angle. When the turn knob is returned to detent, the airplane returns to wings level and is recoupled to the heading reference which exists when bank angle becomes less than 6 degrees. Operation of the turn knob takes priority over any lateral control mode.

(4) Heading Select

(a) The heading select mode operates through the roll axis to establish and follow a chosen heading set on the course indicator or equivalent heading display. The heading select cursor on the indicator is positioned at the desired heading by using the heading select sync knob. With the navigation selector switch set to heading select, the airplane is automatically banked at a controlled roll rate up to a limited bank angle to execute a turn toward the selected heading. As this heading is approached, the airplane is smoothly brought to wings-level. The airplane is aligned with the selected heading and is directed to maintain that heading until new commands are given to the autopilot.

(5) Localizer/Omnirange

(a) The roll channel computer provides aileron control in response to lateral radio signals (VOR and ILS) if the navigation selector switch is rotated to LOC/VOR and the navigation receiver is tuned to the proper frequency. Desired omniradial heading or inbound runway heading must be set on the pictorial deviation indicator.

(b) Automatic beam capture is initiated by the pilot establishing an appropriate intercept heading by using either the turn knob or heading select mode. After the airplane rolls out on the intercept course, rotating the navigation selector switch to LOC/VOR establishes heading hold until lateral beam intercept.

(c) At beam intercept, the airplane turns toward the transmitting station at a limited bank angle that is a function of beam error, rate of change of beam error (ILS only), and course (runway) heading error. When the airplane attains the selected radial at beam center (on-course) the autopilot automatically integrates the crosswind correction. As the airplane approaches the zone-of-confusion above the VOR transmitter, interlocks decouple the beam signal, and the airplane is directed to fly at the drift-corrected radial heading. After passing the VOR station, the beam is again switched into roll command circuitry, and the autopilot tracks the outbound radial.

(6) ILS

(a) With the navigation selector switch set to ILS at a specified beam error, glide path control is initiated. The pitch channel computer controls descent to glide path beam center localizer while the roll channel computer maintains the airplane on beam center to minimum altitude or disengagement.

(b) Interlocks prevent selection of ILS unless the pitch axis is engaged and appropriate radio receiver is tuned to ILS frequency. The navigation selector switch will not hold in ILS, and glide path capture is prevented.

(7) Auxiliary Navigation Control (optional)

(a) The autopilot roll axis can provide automatic control in response to track error and cross-track deviation information received from an auxiliary navigation system to maintain a selected ground track or sequence of ground tracks. Auxiliary navigation is engaged by pressing and rotating the navigation selector switch to AUX NAV after setting the initial conditions in the auxiliary navigation controller. Upon engagement, the airplane is automatically turned to intercept auxiliary navigation. Auxiliary navigation control of the airplane is implemented only in airplanes equipped with auxiliary navigation system.

C. Pitch Axis

(1) Synchronization

(a) With pitch and roll axes circuit breakers closed and power applied, the autopilot provides continuous synchronization to airplane pitch attitude, vertical speed, and altitude. This synchronization provides a null output from the elevator servo amplifier to the elevator servo drive motor prior to engagement.

(2) Pitch Axis Engage

(a) The pitch axis is engaged when the servos engage lever on the automatic pilot controller is moved to autopilot. The servos engage lever is held at autopilot if all engage path interlock requirements are met.

(b) When engaged, the pitch axis provides a vertical speed hold function. This is the primary pitch control mode. This mode adjusts the pitch attitude of the airplane to maintain the vertical speed existing when the pitch axis was engaged. The vertical speed hold function continues until changed by use of the vertical speed wheel on the automatic pilot controller.

(c) Automatic disengagement of autopilot control occurs when the pitch axis monitor detects a malfunction within the pitch axis. The servos engage lever drops to yaw damper and the autopilot off light comes on as an indication to the pilot. The yaw and roll axis may be operated by using the split-axes servo switches (see paragraph D).

(3) Vertical Speed Control

(a) The detent (center) position of the vertical speed wheel is altitude hold (zero vertical speed). During synchronization, the motor-driven vertical speed wheel follows up to the vertical speed of the airplane, providing a vertical speed reference for the vertical speed hold function at engagement.

(b) When the vertical speed wheel is moved out of detent, the airplane assumes (and adjusts as required) a pitch attitude to hold the commanded vertical speed. The pilot observes the rate of climb or descent on the vertical speed indicator and manually adjusts the vertical speed wheel to obtain the desired vertical speed. The pitch selector switch returns to vertical speed when the vertical speed wheel is manually moved. The navigation selector switch returns to turn knob when the airplane is under glide path control mode if the vertical speed knob is manually moved. If the system is in the glide path extension mode and was manually or automatically engaged to this mode, manual movement of the vertical speed wheel reverts the system to the turn knob and/or vertical speed modes.

(4) Altitude Hold

(a) Altitude hold is established when the vertical speed wheel is at altitude hold (zero vertical speed). The airplane altitude existing when the vertical speed wheel is returned to the detent (altitude hold) position is maintained until a change in vertical speed is commanded.

(5) Pitch Damp

(a) When the pitch selector switch is pressed and rotated to the pitch damp position, the pitch damp mode is initiated. During this mode, which is used for turbulence penetration, automatic pitch elevator trim is disconnected. Pitch trim is accomplished by manual actuation of the horizontal stabilizer controls. A "soft" pitch attitude clamp function is provided by the autopilot to minimize pitch rate deviations. There is no vertical gyro pitch attitude reference during operation of pitch damp mode.

(6) Glide Path Control - Automatic

(a) The autopilot pitch axis provides automatic glide path control from signals received from a glide path receiver. The system automatically captures the glide path beam when the pitch axis is engaged, the glide path receiver is tuned to an ILS frequency, and the navigation selector switch is at ILS. At glide path capture the pitch selector switch returns to vertical speed if the switch was at another position.

(b) A 10-second capture period begins at glide path capture. During this period, a fixed vertical speed command is applied to the pitch channel computer, causing the airplane to descend at approximately 700 feet per minute. The vertical speed wheel follows up to this commanded rate of descent.

(c) After the 10-second capture period terminates, the airplane is in the glide path control phase. In this phase, the airplane follows the glide path beam.

(d) The vertical speed wheel follows up to the rate of descent during the control phase. Heading, localizer, and glide path gain programming are initiated as a function of radio altimeter altitude (analog dc output). If the radio altimeter malfunctions, localizer and glide path gains are programmed at glide path capture to compensate for ILS beam convergence. The control phase ends when the pilot terminates the automatic approach to land the airplane manually.

(7) Glide Path Extension - Manual

(a) The glide path extension mode is manually engaged by placing the pitch selector switch at G/P EXT. This mode can be used by the pilot to initiate glide path second-stage gain programming only when glide path is energized (capture +10 seconds), the radio altimeter has failed or is not connected to the autopilot, and the middle marker beacon is not passed. If the radio altimeter is disabled or not installed, glide path gains are second-stage programmed automatically upon interception of the middle marker beacon.

D. Split-Axes Operation

(1) The three autopilot (split-axes) servo switches, located on the flight instrument panel, provide independent cut-off of roll, pitch, and yaw control functions of the autopilot. In this manner, the pilot may use manual control in one or two axes while the autopilot retains control of the remaining engaged axes. In addition, even though a malfunction occurs in one or more control channels a portion of the autopilot may still be used. Split-axes operation also provides approach operation with manual pitch axis control.

(2) The roll and pitch channels may be split off individually, but the yaw channel may not. If the yaw channel is to be split off, both rudder and aileron servo switches must be placed in their off position. This is necessary due to roll channel dependence on yaw damper for proper performance.